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U.S. Department of Transportation
Federal Aviation Administration

Proceedings of the Public Workshop on Alternative Separation Concepts:
Presentations, Discussions and Recommendations

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held Atlantic City Airport, New Jersey, January 7, 8 and 9, 1981.

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16. Abstract

This report documents the proceedings of a Federal Aviation Administration (FAA) public workshop on Alternative Separation Concepts during January 7-9, 1981. The first day was devoted to presentations describing FAA/NASA ongoing programs to improve the ATC system with an emphasis on those aspects which would directly improve the services offered to pilots. These improvements would primarily ease the entry into and exit from the IFR system, and the accommodation of pilot preferred routings. The second and part of the third day were devoted to participant discussions which are unrecorded. There were three working groups, technical, procedural and economic which reported their recommendations at the close of the workshop. The participants at the workshop did not identify a fundamentally new concept for air traffic control. They concluded that it would be desirable to continue development of existing and planned Secondary Surveillance Radar-based systems. The promising approaches to system improvements to permit a greater degree of freedom of GA operations were classified by the availability of surveillance services. Within ground-based surveillance coverage, and automatic ground-based primary separation service was the recommended approach. Outside of surveillance coverage, an airborne-based primary separation service utilizing the signal format of the improved secondary surveillance radar system was recommended for further development.

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ABSTRACT (cont'd)

Operations which would permit a measure of self-separation with either of these two systems were tentatively called Electronic Flight Rules (EFR). Changes to the Federal Aviation Regulations would be required in order to allow EFR operations. The participants recommended some changes that they believed would have to be made to the regulations after the development of either or both of these techniques.

The participants prepared a preliminary benefit/cost analysis. The lack of definitive cost data made the accurate analyses of the concepts impossible to make during the workshop. As more data becomes available, it may be possible to use the framework developed at the workshop to prepare a more complete benefit/cost analysis.

ALTERNATIVE SEPARATION CONCEPTS

A PUBLIC WORKSHOP

held at

FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER

Atlantic City Airport, New Jersey

January 7, 8 and 9, 1981

PROCEEDINGS

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INTRODUCTION

National Aviation System Planners and Managers in FAA and the Aviation Industry have become increasingly concerned in recent years about the ability of ATC System capacity to grow to meet the forecast demands of its users. IFR aircraft handled by FAA Air Route Traffic Control Centers have grown in number about 40% over the past 12-years and are forecast to increase another 40% in the coming 12-years. The historical growth has been accommodated by some growth in controller productivity thru the application of various means of automation but the period has also seen a necessary increase in the number of controllers, sectors, communications frequencies, and hand-offs in order to maintain a safe level of controller workload. Concern has been expressed that we are at our near the point of diminishing safety returns in adding capacity by dividing center sectors.

At the same time some system users are encountering serious delays in gaining access to the IFR system. General Aviation Airports in suburban areas surrounding major hubs frequently encounter substantial delays between receipt of an IFR clearance and "release". Additionally, it is said by many operators that the ATC system should offer more cooperation in accommodating requests by operators for direct or fuel efficient routes and flight profiles.

The search for alternative separation concepts became a major focus of the activities of Topic Group III on "Freedom of Airspace" in the New Engineering and Development Initiatives process sponsored by FAA's Office of System Engineering Management in 1978. Topic Group III enunciated a technical concept it called Electronic Flight Rules (EFR). Expressing a confidence that technical solutions either existed or could be developed, the group debated solutions to procedural problems such as the co-existence of EFR and IFR traffic in airspace under Instrument Meteorological Conditions. Both the Topic Group and a subsequent Study Group at MIT's Lincoln Laboratories which gave the EFR concept a more disciplined study, under FAA contract, felt much more comfortable assessing technical solutions than hypothesizing procedural means to put them into effect.

As a result of the E & D Initiatives process and the Lincoln Labs Study and Report, FAA found itself with a fairly tenuous concept on its hands and no good definitive course of action to pursue in its continued development. Yet in the face of continued capacity constraints of conventional ATC separation procedures, FAA had a serious obligation to continue its search for alternative separation concepts. Toward this end, a Public Work Shop was designed and produced. Its purpose was threefold. First, to brief System Planners and Users on progress in technical programs which might point the direction for alternative separation techniques. Second, in Working Group sessions recapitulate and define the technology appropriate to alternative separation concepts and supplement the technical assessment with a thorough and comprehensive procedural analysis as well as an initial look at the economics of alternative separation concepts. Finally, FAA held the group responsible for producing the clearest possible definition of further work needed to advance any selected alternative separation concept.

It must be emphasized that throughout the Work Shop every possible precaution would be taken to avoid locking the discussion into a single technical alternative as the only visible concept worthy of pursuit. All available technical and procedural alternatives were to be consciously assessed.

This report documents the proceedings of this Public Work Shop.

BACKGROUND

During the past decade there have been several developments which have caused airspace users to raise the possibility of alternative means of separating aircraft during Instrument Meteorological Conditions (IMC). These developments include but are not limited to:

1) A change in the capability of the existing system, to expand its capacity and to increase the ease of accessibility by users to the system.

2) Airborne electronic devices which would allow a pilot to perform self-separation in certain airspace.

3) Change in rules, operations and/or procedures in IMC which might safely permit more freedom of operations without full participation in the ATC system.

4) Some combination of the above depending on traffic density and aircraft equipment.

The following background is based primarily on discussions held during the FAA New E&D Initiatives Process, and results of the FAA/Lincoln Laboratory Electronic Flight Rules Concept Development Effort. This background is relatively complete up to the beginning of the ASC public workshop. All of the concepts discussed require further development, and are based on the ideas developed through the efforts of the participants in Topic Group III of the E&D Initiatives.

During Visual Meteorological Conditions (VMC), a VFR pilot today can depart from any uncontrolled airport and fly to any other uncontrolled airport without any ground-based control over his operation, except compliance with altitude and visibility rules.

The pilot's major procedural concern in such a flight is the avoidance of restricted airspace, and that factor in flight planning has existed for many years.

The VFR pilot has seen the establishment of Terminal Control Areas, or TCA's, and new rules for Transponder equipage for flight above 12,500 feet. This presents a restriction imposed by safety considerations to the non-equipped pilot. However, by the addition of the required equipment, that is an altitude encoder.

Transponder, TCA's, and the airspace between 12,500 feet and 18,000 feet are available as in the past. This illustrates that an investment in an airborne service has helped to maintain a level of freedom in the use of airspace with an increase in safety for all users.

This freedom of airspace is also enjoyed by pilots operating on Instrument Flight Rules. An example is in route selection, where the system will usually accommodate requests for direct routings, and users who have made investments in Area Navigation Equipment are finding it easier to obtain clearances for direct flights along randomly selected routes.

Looking to the future, pilots are faced with increasing aircraft density in most airspace. New airspace restrictions could become a necessity to maintain or reduce the present low level of risk of collision.

The members of Topic Group III studying freedom of airspace shared several areas of concern related to the present and projected system of Air Traffic Control. There is, of course, a genuine concern for the statistically increasing risk of mid-air collision as more aircraft attempt to use the same popular airspace volume under essentially all weather conditions. Of perhaps unique importance to Topic Group III was the converse concern that ATC constraints on freedom of access to airspace not be applied unless necessary and justified. And, within these dimensions, there was agreement within the group that an effort to continue to manage premium airspace in the face of steadily increasing demand by using the same procedures and control techniques and facilities as are in use today, will certainly constrain capacity because no conscious compromise of safety can be countenanced.

The most visible growth component of airspace users is the General Aviation Fleet, which presently numbers over 200,000 active aircraft. Unless constrained by natural or artificial means, this number is projected to double before the end of the century. While it is presently forecast to grow at an annual average rate of about 4%, it is critical to note, for the purposes of this report, that the growth in IFR activity is forecast to exceed the rate of growth in fleet size and hours flown.

In the last few years, the helicopter fleet has been growing at an annual rate in excess of 12%, three times the rate of growth of the total General Aviation Fleet. Industry forecasts estimate a helicopter fleet of over 10,000 by the mid-1980's, with about 5,000 of this number capable of IFR operations in Instrument Meteorological Conditions.

It is doubtful that the projected growth in demand can be accommodated in the procedures, techniques and facilities presently applied by ATC to manage the safe and efficient flow of air traffic. So it is necessary either to modify the "constrained" forecast of growth to add the constraint of limiting capacity at acceptable safety standards, or to seek new alternative or supplementary aids to the existing system of Air Traffic Management so that its capacity can grow at a rate equal to, or in excess of, the anticipated rate of growth in demand, while providing safety equal to, or better than, that which exists today.

EVOLUTION OF EFR CONCEPT

Early in the deliberation of Topic Group III, it was acknowledged that the capacity of a given volume of airspace was greater in Visual Meteorological Conditions (VMC) with aircraft separated in accordance with Visual Flight Rules (VFR), than it was in Instrument Meteorological Conditions (IMC), when aircraft are separated by Instrument Flight Rules (IFR). The amount of difference in capacity varied, depending upon other conditions, but it appeared to the group that with the exception of the top 25 very high density terminal airspaces, there would be no capacity limitation today, or in the forecast future, if aircraft could be safely separated in IMC using the criteria applied under VFR. This concept was variously called Electronic VFR, Electronic See-and-Avoid, or Electronic Flight Rules, at various stages in the group's discussions.

This concept would allow suitably equipped aircraft to use today's VFR operating procedures in certain airspace under IMC, and to operate in this airspace without all the constraints of an IFR Flight Plan and ATC clearance.

The group recognized that EFR is fundamentally different from Collision Avoidance (CAS). The latter refers to backup techniques or systems which attempt to provide for safe aircraft passage in the event of a failure or absence of the primary mode of traffic separation (ATC). EFR, on the other hand, assumed primary responsibility for separating aircraft, and, in cooperation with ATC, from aircraft operating under IFR clearances.

The group recognized certain limitations of EFR, including initial applicability only in lower density airspace, and the need to interact with conventional ATC. However, the group believed the EFR concepts showed promise of alleviating ATC-induced constraints and it recommended the FAA pursue an aggressive E&D program to examine and fully evaluate means of realizing this concept.

An expansion of the EFR concept declared that EFR may be feasible in airspace that is under the surveillance of DABS Interrogators for those aircraft which become equipped with DABS Transponders. This procedure would permit a DABS equipped aircraft to fly in IMC without necessarily filing any or a complete Flight Plan in airspace that was under DABS-type surveillance where the traffic density is sufficiently low so that knowledge of aircraft intent is not essential at all times for sepration safety. There could be no limitation to the use of this same airspace under IMC conditions by IFR qualified pilots in precisely the way they use the airspace today.

A DABS equipped aircraft and pilot flying EFR must be qualified to fly in IMC and must abide by the terminal procedures in effect at the origin and destination of his flight. En route separation from aircraft flying either EFR or normal IFR procedures is provided either by the DABS/ATARS operating in a traffic separation rather than collision avoidance mode or by an AERA type en route center computer. When the projected flight vector of an aircraft flying EFR procedures is computed in the ground system to come within an "avoidance volume" of the projected flight vector of another EFR aircraft or that of an aircraft flying normal IFR procedures, a data linked message is transmitted to either both EFR aircraft or the single EFR aircraft, and the controller responsible for the IFR aircraft. The data linked message to the EFR aircraft contains a traffic advisory and perhaps a request for flight intent or a temporary maneuver restriction or instruction that will prevent the two aircraft from occupying the "avoidance volume" simultaneously.

The practicality of such a procedure in any airspace depends on the relationship of the "avoidance volume" to the traffic density and the aircraft's capabilities and therefore the rate at which Traffic Advisories and clearances have to be transmitted to aircraft flying EFR procedures. Therfore, additional analysis is required to determine the practicality of EFR.

The EFR procedure, as described, seems capable of meeting these developed operational requirements:

1. EFR must be capable of evolutionary implementation; i.e., the equipped user must be able to realize benefits of EFR without equipage of all aircraft using the airspace involved.

2. There must be no derogation in the safety of conventional IFR operations.

Should such an EFR procedure become practical, the anticipated benefits are:

1. There would be decreased dependence on conventional IFR ATC procedures by EFR-equipped aircraft.

2. The aircraft operator would save time and cost as compared to present IFR procedures where Flight Plans must be filed and approved by FAA.

3. FAA, by gearing its requirements for information on aircraft intent to the level of control needed to maintain safety, can expedite flight under IMC conditions at lower costs.

SOME POSSIBLE EXTENSIONS OF EFR

While EFR is focused primarily on providing for uncontrolled operations in IMC with little or no controller intervention, it should be able to provide increased safety in VMC as a backup to VFR procedures in airspace under DABS surveillance. In other words, the ground ATC system could operate in a traffic avoidance, as well as collision avoidance mode under VFR as well as IFR.

EFR might be feasible before DABS surveillance is available. An aircraft equipped with an altitude encoding (ATCRBS) Transponder might fly EFR, receiving traffic avoidance instructions by VHF to avoid IFR traffic. The pilot would have to monitor communication channels, however, so the reliability of the communications link, and the controller workload if it is a manual system, would require careful analysis to determine the safety and benefit of EFR with this level of equipage.

Another concept proposed by Capt. William Cotton of ALPA which was discussed but not endorsed by the members of Topic Group III was referred to as pilot-based ATC concept. The concept for providing opportunity for greater pilot involvement in the ATC process is one which is based on, and is consistent with the current ATC system. The approach is to augment the current type of ATC services with a special set of beneficial clearances, which are provided to operators who choose to purchase special avionics and who choose to take on greater ATC responsibility with regard to their own aircraft. These special clearances may provide the operator with opportunities for improving his flight's efficiency in terms of reducing flight time, and may provide him with more freedom in using the available airspace. There are potential safety benefits

as well. Finally, if a large enough set of operators choose to equip, it can be postulated that potentials exist for increasing airport capacity, improving ground operations and reducing the ratio of Air Traffic Controllers to flights.

For this concept, the set of avionics required to provide an operator with the greatest opportunities for involvement in the ATC process consists of:

1) Area Navigation Computer (with stored airway and airport maps).

2) Weather Radar

3) Data Link Receiver

4) Integrated traffic and ATC information display

    a) Navigation Map (R-NAV)
    b) Weather Information (Weather Radar)
    c) Traffic Information (Data Link or on-board sensor)
    d) ATC Information (Data Link)

5) Collision Avoidance System (either air derived or provided from the ground via Data Link, assuming duplicate ground coverage).

In order for an operator carrying this set of equipment to be able to receive the fullest opportunity to involve himself in the ATC process in a given airspace, all other aircraft in the airspace in question must carry a Transponder and an Altitude Encoder. Some airspace already requires this equipment. If the proposed system is adopted, the airspace used by Air Carrier airplanes would eventually require Mode C Transponders.

Another variation was proposed by Mr. David D. Thomas. This concept has as ultimate goals:

- Air traffic delays should be caused only by runway or approach path occupancy.

- Air traffic restrictions to flight will be imposed only because of potential actual conflict with other aircraft and not because of procedures internal to the ATC system.

- The system should be able to resolve potential conflicts in operationally acceptable ways.

- System implementation should be evolutionary (i.e., benefits not dependent upon full implementation).

- The ATC system workload (manpower intensity) will be reduced significantly.

There is no known technique that will satisfy the ultimate goals. Therefore, goals that have prospects of being achieved and which lead in the direction of satisfying the ultimate goals should be considered for a transition period which probably will require two or more decades. Additional concepts that will govern the transition period could include:

- Only cooperating airborne equipment will be considered unless some revolutionary breakthroughs in self-contained equipment occurs.

- Equipment carriage will not be mandatory and non-equipped aircraft will be permitted to operate IFR and VFR in all controlled airspace.

- In controlled airspace, ATC must be able to exercise control or intervene.

- Communications with ATC are required at General Aviation Airports underlying controlled airspace to provide for efficient control of IFR aircraft departing from those airports.

If these additional concepts are accepted as realistic for the indefinite future, it is clear that:

- The airborne equipment would have to cooperate with the ground ATC system and other equipped aircraft.

- Some type of Flight Plan would be needed by ATC in advance of departure. As a minimum, destination and desired altitude could be given while taxiing out for takeoff.

- Within controlled airspace, conflict resolution could probably be done beset by a ground computer. Airborne computation capacity could be limited to that needed for "backup" collision avoidance.

SUGGESTED DEVELOPMENT PROGRAMS

The above ideas lead to the conclusion that an "Electronic See-and-Avoid" system that will permit IFR operations within controlled airspace while completely cooperative with and not

independent of the ATC ground system is achievable with today's technology, but is not yet economically viable. Therefore, the concept should be retained and pursued as an E&D initiative. In the meantime, the FAA E&D effort should be expanded on automating the ground system to reduce controller involvement with continued development of a complementary airborne device which will serve as a backup collision avoidance instrument.

Based on the recommendations of the New E&D Initiatives Topic Group III, FAA entered a contract with Lincoln Laboratories for further study of EFR. A set of ground rules was established to bound the Lincoln Labs study as follows:

1. The safety of EFR operations and EFR co-existent with IFR operations must be equal to or better than the safety of conventional IFR operations.

2. The implementation of EFR must be evolutionary. Benefits to users who equip for EFR should be perceived during initial implementation stages.

3. The implementation of EFR must not require airspace segregated to EFR operations only.

4. EFR operations must not require additional special equipment in conventional IFR aircraft.

Point 4 above may need to assume that by the time EFR could be implemented, all conventional IFR aircraft would carry either an ATCRBS or DABS/ATCRBS Transponder with altitude reporting.

While it may not be possible to implement EFR without adding special equipment to the EFR aircraft, the cost of carrying this equipment must be commensurate with the benefits perceived.

TENTATIVE LINCOLN LABS CONCLUSIONS

Thorough study of the EFR concept under the constraints identified above concluded that:

1. Substantial user and system benefits would accrue if the concept could be implemented.

2. Implementation of EFR through surveillance and communications of DABS would be feasible only in DABS airspace and would exclude much low-altitude airspace and many uncontrolled airport approach zones.

3. Implementation of EFR by carriage of an "autonomous" on-board device would not provide adequately reliable conflict avoidance. Coordinated resolution actions would be required of aircraft in conflict, thus violating ground rule 4 above.

Conclusion 3 may not be consistent with the logic which supports the development of the beacon-based Collision Avoidance System (B-CAS). FAA and the airlines are moving rapidly to finalize standards for B-CAS which will coordinate conflict resolution between two B-CAS equipped aircraft, but be autonomous in conflict with all other (Transponder with Mode C equipped) aircraft.

SOME TERMINAL CONSIDERATIONS

Lincoln Laboratories did not consider the terminal/en route interface. This is where ATS/APAS may have a useful function.

FAA's Automated Terminal Service (ATS) is an advisory system in that it advised participating aircraft about airport weather conditions and runway in use, possible conflicts, traffic at pattern entry, landing sequence, and the position of non-participating aircraft that are Mode C transponder equipped. It is traffic management service in that it can warn aircraft that are straying from the pattern, order a temporary halt of touch-and-go operations if the traffic pattern becomes too congested or the departure queue gets too long, and communicate runway changes when warranted by wind conditions. ATS would require all participating aircraft to be quipped with a transponder.

NASA's Automated Pilot Advisory System (APAS) is designed to serve all aircraft in an uncontrolled airport traffic pattern by relying on primary radar. Instead of requiring that all participating aircraft be Mode C transponder equipped, APAS would provide altitude segregation through multiple lobes in the primary radar vertical antenna pattern.

The exact role such systems could play within an ATC system that allowed some self-separation needs more development. However, these along with other planned capabilities may permit the realization of the goals of the users in the area of freedom of flights.

WELCOME TO THE FAA TECHNICAL CENTER

Joseph M. Del Balzo

Federal Aviation Administration

Welcome to the FAA Technical Center. We're not sponsoring today's symposium - we're hosting it for the Office of Systems Engineering Management in Washington. My name is Joe Del Balzo; I'm the Director of the Technical Center. We're very happy that you cculd join us here at the Technical Center in the new building that we're very proud of. We moved into the building in May of 1980. We're still suffering from a lot of moving in and growing pains. As you can see there is still a lot of construction going on in the lobby. We're at a point, I think, in the construction program where you normally are when you're either building a house or writing a computer program. You get to the 95% or 96% point and you never seem to finish. The contractors and maybe the computer programmers seem to lose incentive to finish the job. They're always refining and fixing things. That's where we are right now. Hopefully in another three months that will all be behind us.

We're proud not only of the building, we're proud of what we do in the building. There's a lot of good work going on. I think that you're probably aware that we recently finished the evaluation of the DABS ground sensors leading up to the writing of a technical data package which will be used by Airway Facilities for the first production buy. We recently finished a comprehensive program on Active BCAS in support of the issuance of a National Standard. We're gearing up now for a test program on Full BCAS. We're preparing ourselves for the evaluation of cockpit display of traffic information and there are a lot of other good programs going on; programs that will have a significant impact on the ATC system of tomorrow.

Our job during these three days is to be sure that you are well looked after administratively. We're here to provide any services that you may require. There will be people stationed outside who can arrange briefings on programs of interest to you. If you would like to talk to me I'll be available. Just give me a call.

Again, I welcome you here to the three day conference. The subject is certainly an appropriate one for this time. It's a subject that can have a significant impact on Air Traffic System capacity. I wish you all a productive three days.

Let me introduce Quent Taylor who is the Deputy Administrator of FAA and I think you all know that. We are pleased and proud to have him with us today - the Deputy Administrator, Quent Taylor.

OPENING REMARKS

Quentin S. Taylor

Federal Aviation Administration

Joe, thank you very much. I'm particularly happy to welcome you all to this conference and to this Work Shop on Alternate Separation Concepts. We've asked you here to have you share with us your ideas on making the Air Traffic Control System better and certainly more efficient for your use and for our operations. This Work Shop is one of the products of the extensive user consultation process that we called some time ago - New Engineering and Development Initiatives; Policy and Technology Choices. During that consultation process the user community recommended among many other suggestions that the FAA explore concepts by which freedom of airspace could be enhanced without compromising efficiency and certainly without compromising on safety.

The broad outlines of a concept called Electronic Flight Rules were postulated by the users as an approach to permitting freedom of operations particularly in low density airspace with aircraft operating under instrument weather conditions, without having to be full participants in the Instrument Flight Rules Air Traffic Control System.

Now pursuing the user recommendation, the FAA has explored the concept and you will be hearing the results of that exploration today. It will become apparent to you certainly that more work is needed on your part, and certainly on our part to flesh out the skeleton of this particular concept. It will also be clear to you that new and alternative separation concepts must be studied in the context of other work going on within FAA and within the industry. And we'll discuss some of that work with you. That is work on automated Air Traffic Control and cockpit displays, traffic information, on the Discrete Address Beacon System, Automatic Traffic Advisory and Resolution Service (ATARS), the Beacon Collision Avoidance System and Automated Airport Advisory System.

You will also hear about planned changes and improvements to the Air Traffic Control System as it exists today, especially in the procedural context. And I hope that the background that we shall sketch for you stimulates your creativity stimulates your imagination with respect as to what might be done using other separation concepts, particularly the electronic separation concepts I have just spoken about.

The FAA is as dedicated as you are to assure freedom of the airspace consistent only with our responsibility to assure safety. And we are prepared to listen to better ideas. We are prepared to work with you to explore innovations of one kind or another. And we do want practical, workable recommendations that can make the system certainly better.

With the demands upon the system growing, the system must become better. The Air Traffic Control System and the participants in it are both changing. Aircraft mix is changing dramatically and we are on the threshhold of a major effort to replace our Air Traffic Control Computer System. And that system will be flexible enough to adapt to useful changes in procedures and in system operations. So we have a valuable opportunity today and tomorrow to step back and look for better ways, more efficient ways to serve the ever growing General Aviation community especially in areas of relatively low traffic density. We want your thinking, we want your imagination, we want hard-headed practical ideas with respect as to what might be implemented and what can be of benefit to aviation.

Now those of you who attended the User Conference last January at which we reported the FAA response to the Engineering and Development Initiatives recommendations should recall the presentation on the FAA's scenario for the system at the turn of the century. We have been refining that scenario in an effort to create a development and implementation roadmap. I'm not going to go into the details of that future. But let me say this. In it we recognize the possibility and potential for alternative separation concepts and possible schemes for self separation in certain airspace, particularly the low density airspace.

And I hope and expect that you will be able to reach conclusions during your time here and make recommendations in this Work Shop because specific proposals and recommendations are a practical way to achieve meaningful change. I do wish you a successful conference and Work Shop. And I also anticipate from this particular Work Shop that we will develop notions, schemes, at least schematics of alternative separation assurance concepts that will be useful in our aviation future. Thank you for being with us.

Gilbert F. Quinby

G. F. Quinby Associates

Thank you very much Quent. My name is Gil Quinby. I am deeply grateful and very appreciative of your presence here today. You constitute a resource which we want to make work and that's the purpose of this meeting. It's also been called by a couple of our friends here a meeting of the alumni association of Group III of the E & D Initiatives Process and to those of you who suffered through that a special welcome.

We have an Agenda, but the product of our Work Shop is not going to be slaved to the Agenda. We'll use the Agenda for a guide, we'll depart from it if departure will improve the product of our work. Today is a time for listening and learning. Presentations by FAA and FAA Contractor Personnel will bring us up-to-date, questions answers will be devoted to a clarification of the material presented and assurance of understanding of all of us of the meaning of the presentations. Tomorror is when we get into a discussion of the substantive issues involved.

There will be two primary working groups that will run at least all day tomorrow. There will be a dependent working group that will convene ad hoc when it has material that it can constructively deal with from the other working groups. I'd like at this time to introduce the Chairmen of the Working Groups; the Technical Working Group will be chaired by Stan Halverson. He was Chairman and President of NARCO Scientific Industries and took an active interest in the Avionics and AIM Instrument Divisions. He is now a Consultant actively serving clients in the field of Corporate and Business Aircraft. There is a Procedures Working Group which will deal with the interaction and co-existence of whatever we're talking about with the orthodox IFR and VFR flight procedures. And we have Bill Flener to chair that group. Finally, the dependent Working Group on Economic Aspects and Considerations of Alternative Separation Concepts will be chaired by Dr. Dick Jensen of Ohio State University.

Are there any questions about the administrative details of the Work Shop so far? Thank you.

It's my privilege now to introduce Dr. Ed Koenke who is here from Seig Poritzky's Office of System of Engineering Management. He will present the background papers on which all the work today is based and will also introduce the presenters for the rest of today's activities.

ALTERNATIVE SEPARATION CONCEPTS

BACKGROUND AND GROWTH FORECAST

Edmund J. Koenke

Federal Aviation Administration

Good morning. Before I begin my official presentation, I'd like to mention that Sieg Poritzky who is the Director of Systems Engineering Management really would have liked to have been here and he sends his regrets but he had to be in Los Angeles, Denver and Chicago for public meetings discussing MLS transition issues this week.

What I'd like to do with the time that I have is to try to put in context the problem as I see it and the problem that we're going to be wrestling with for the next three days. It seems that at least from my perspective there is a dissatisfaction on the part of General Aviation users with the delays that they seem to encounter when trying to enter into the IFR system as we know it today. We see that the IFR system has grown over a number of years and the delays that are encountered are primarily to ensure the safe operation of that system. There seems to be a desire on the part of General Aviation, again my perception, to have the same freedom of flight during instrument meteorological conditions as are enjoyed during visual meteorological conditions under VFR flight rules. Topic Group III of the New E and D Initiatives Group recommended that FAA investigate Alternative Separation Concepts and specifically take a look at what was called Electronic Flight Rules.

Before I get into a discussion of the E and E Initiatives and Electronic Flight Rules, I think it's important to talk to the problem not only from the perspective of the growth that we see occurring within the system and within aviation as projected to occur over the next decade. Many of you may have been at the Aviation Forecast Conference but I would just like to highlight a few numbers for you. We expect enroute IFR handles to grow at a rate of about 3.2% per year. We expect fuel utilization to be growing at about 2.8% per year. We had a 9-billion dollar fuel bill for aviation in 1979.

We had about a 1-billion dollar Air Carrier delay bill in 1979-1980, and this is forecasted to possibly grow to something like 8-billion dollary by 1990. Now that's ridiculous; it will never happen because there will be other constraints that will be exercised to prevent that. But that's in the black magic of forecasting. There is forecast a tremendous change in the mix of aircraft that will be using the IFR system. Commuter aircraft for example will comprise a much larger percentage of the population. So I think we can take an opportunity nere specifically because of the Commuter and General Aviation growth, to try to examine the system as we know it today and to try to arrive at some definitive alternative concepts for how we might be able to satisfy the perceived needs of the users that I've just talked about.

In the E and D Initiatives discussion, particularly in Topic Group III, a number of procedural approaches to solving the problems that I've just outlined were discussed but no recommendation came out of those discussions to the FAA. And I'd like to encourage that this work shop take another look, a hard look, at procedural approaches for solving these problems. The thing that did come out was an airborne based electronic equipment concept for traffic separation. This most promising concept was referred to as Electronic Flight Rules. Now what FAA did as a result of that was to take a look at these recommendations and to go to Lincoln Laboaratories and to ask them to study the concept. And they did that. They published a report. The report is available outside this room. I don't know whether you've gotten it yet, but copies are available there are copies here for everyone. That report was published and as a result of that report we decided to hold this Work Shop and the decision to hold the Work Shop did not come easy. We had toyed around with a number of alternatives as to how to take the next step after Lincoln Laboratories published this report. We thought about going to other contractors, we thought about extending the Lincoln Laboratories work and we stepped back and said, no, we think it's time we asked the users to come back and to take another look and to try to get more definitive with the concepts that they are proposing and that's why we're here.

Now the goals of this Work Shop as I see them are to review the proposed concepts by Topic Group III, to evaluate, not in a detailed way because we've done that, but at least to become extremely aware of the work that has gone on by taking a good hard look at the EFR concepts in the report that is available. What we would like to do is to consider any concept which might really help to solve the problems to provide more freedom of airspace to the General Aviation users specifically in instrument meteorological conditions. Also we'd like to compare these concepts and recommend only those concepts that are realistic and feasible. Specifically I would like to reject concepts that are

vague and general and basically say to FAA well, this might be a nice idea why don't you go and spend some money and see and then come back and let us know how it works. That's not what we're trying to do here, what we're trying to do is to get some very, very definitive concepts that we can evaluate and take the next step on.

Let me turn to the EFR concept (Electronic Flight Rules). It is, I think, a keystone of this Work Shop and I would like to talk about EFR and some of the other programs that you're going to be hearing about so that hopefully I can put them into some kind of context before you get into the technical details of this program.

There are a number of constraints that Lincoln was working with when they were developing the EFR concept. One of the assumptions that was made or constraints that they were working under was that the safety of EFR operation had to be the same as IFR. In other words, EFR had to co-exist with IFR and the safety had to be equal to or better than the safety of the conventional IFR system. Also, the implementation of EFR had to be evolutionary and benefits had to exist for users that equipped during the initial implementation stages. The implementation of EFR must not require airspace segregated to EFR operations only. That means it had to co-exist with IFR operations and also something that is not mentioned and is kind of glossed over is that it also has to exist with VFR operations. Because IMC isn't everywhere all the time. And EFR operations must not require additional special equipment in conventional IFR and I'll add VFR aircraft.

Now their conclusions were that there must be a coordinating resolution of actions between aircraft. What that means is that when aircraft came in some sort of conflict with each other, not necessarily collision but where a perceived violation of separation would occur that autonomous resolution of that problem was unacceptable, in other words, there had to be communication between two EFR aircraft, and EFR and IFR aircraft, and I will add EFR and potentially a VFR aircraft. They suggested that computer decision-making was preferable to having the controller try to resolve these problems.

Another conclusion, and I think that it is something that we'll have to be discussion here these three days; Altitude Reporting Transponders will be required and DABS is preferred. In mountainous regions, coverage by a ground independent surveillance and communications system which would have to be developed.

Computer algorithms used for EFR should utilize a cost function structure and issue instructions in terms of

specified heading or altitude. Lincoln Lab looked at saturation of this concept and concluded that even with the 1990 densities that were used for the basis of the EFR study that only within 10 to 20 miles of a few busy hubs would saturation possibly occur. And I'd like to point out that the densities that were used in that study were higher than the forecasts which I have just talked about. So I don't think that saturation is a major problem.

Lincoln Laboratories went on to identify a number of potential benefits of EFR, these were not really quantatively justified but they are aualitatively perceived as potential benefits for EFR. The EFR system may absorb much of the expected growth in the IFR system loading. That's to say that with commuters trying to enter into the EFR system with other General Aviation trying to enter into the IFR system, that there is a potential for offering this other level of service which would off-load the IFR system. Not do away with it; off-load it. EFR may be less expensive on a per aircraft basis than the current IFR system, Flight Service Station workload may be decreased and fuel efficient departures and paths may be allowed.

Let me just re-cap for a moment. I think that Lincoln Laboratories has done a conscientious and excellent job on the EFR concept that was developed. I also believe that there are a number of areas which were not treated, problems such as how to get in and out of terminal airspace, for example. Problems of how do you deal with VFR aircraft which may be in that airspace. A number of concepts have been identified to date, and have either technical, economic or implementation problems. And the concepts that we come up with we have to look at from technical, economic implementation prospective, so that we don't have the same problem coming out of this Work Shop. We're looking for positive guidance from this Work Shop, we've spent a quarter of a million dollars based upon the recommendations of the E and D Initiatives Group trying to put some flesh on the bones of this concept and we're ready to take the next step. But, it's very possible, depending upon the outcome of thiw Work Shop that that program could be deferred. So, I think we're looking for some very, very strong recommendations.

Now, you're going to be hearing later on today about the details of the EFR study, B-CAS, DABS, ATARS, 9020R and a whole bunch of acronyms. Let me go through some of those for a minute for some of you who may not know what they are. DABS - Discrete Address Beacon System. B-CAS - Beacon Collision Avoidance System. ATARS - Automatic Traffic Advisory and Resolution Service. 9020R it's the computer replacement system for the existing enroute computers. AERA - Automated Enroute Air Traffic Control. Look towards the '90's for this kind of automation. CDTI - Cockpit Display of Traffic Information. ATS - Automated Terminal Services. APAS - Automated Pilot Advisory System. Those are the acronyms that you'll probably hear a lot about over these next couple of days, I'd just like to briefly go through a few of these items.

The idea of B-CAS, ATARS and Data Link are primarily to provide second or third level back-up to the primary Air Traffic Control Separation Service that's provided today; they're not intended to be primary systems at all. They're intended to back-up the existing system. They have the potential, I believe, of providing a developmental foundation for Electronic Flight Rules and you'll see that Lincoln has used some of these programs in their work. And, I believe, that these programs are near term enough that they are likely to be available within a couple of years for B-CAS and a few more for DABS and ATARS. But certainly mid to late '80's.

Computer replacement program - here's another program which I think is really necessary for us to consider in our deliberations about Alternate Separation Concepts because right now we are preparing specifications for the replacement computer for the enroute system. And if the concepts that come out require additional capacity, or functions, on the part of that computer it would be very, very nice to know that up front and to know it now. Don't overlook the possibility of extending planned automation programs as a potential solution to the perceived problem. It may be that what we want to do is to add to what we have as opposed to putting something new in. We believe that the computer will accommodate projected capacity and will provide the pilot with direct access to the computer or could provide the pilot with direct access to the computer for flight plan filing. And it has the potential for automated acquisition of aircraft in flight given DABS and its Data Link. And the capability to handle pilot preferred routing. In other words, the pilot can get the route that he wants. Plus the capabilities of this computer to look ahead in time and sort out the many variables that are involved in being able to give a direct route.

The automated enroute air traffic control work that we're doing is basically automated decision-making. We're talking about a system which is fully automated, managed by humans but a fully automated decision-making computer. Separation service will be provided by a computer. It would plan conflict-free, fuel-efficient metered profiles for aircraft operated in controlled airspace in IFR. Maybe we would want to think about how something like that might be extended to accommodate the needs of General Aviation. Certainly we have to consider whatever we come up with would at least be able to co-exist with that type of automation. And you'll hear more about that program.

Cockpit Display of Traffic Information (CDTI) is one concept where information that is known on traffic to the ground surveillance system can be data linked to the aircraft by the DABS Data Link and displayed on a CRT in the cockpit. Or, it could be independently driven by a Beacon Collision Avoidance System which in fact is doing its own surveillance. Can that suffice as a self-separation concept? It is something which

has to be looked at. The FAA currently has a CDTI program which Harry Verstynen will present describing the ongoing program, and initial findings at greater length this afternoon.

The automated terminal service - you'll hear more about this again, in fact we have a movie on this program and we'll show that to you later. The automated terminal service was an effort to demonstrate that you can provide at least advisory level services to aircraft in a terminal area without human involvement. We successfully demonstrated that this could be done, we provided computer generated traffic advisories, automatically by means of a computer generated voice-over on a VHF communication channel, we provided conflict advisories, we provided some traffic management service and a number of other services. Technical Center personnel helped us significantly to get that program running.

Concurrent with that program, we had an inter-agency agreement with NASA, and they were working at solving the problem slightly differently. They were working the problem using primary radar only. And using a broadcast mode as opposed to using a Discrete Address Mode, utilizing a Transponder which was the FAA approach. The results of those experiments have led us to believe that we should take the best elements of both of those approaches and combine them in order to come up with a viable, acceptable product for the users.

Let me xummarize. There is a change in the capability of the existing system coming. The change is that it will be able to expand its capacity and increase the ease of accessibility to the users of the system. And here I'm speaking specifically of the computer replacement program, automated flight service stations, that kind of effort that's going on. Airborne electronic devices are practically here which may allow a pilot to perform self-separation in certain airspace. We have to consider changes in rules, operations and/or procedures which might safely permit more freedom of operations without full participation in the ATC system. And one thing that I think that is very important is that combinations of these things may be considered, not one or the other. Finally, I'd like to close with saying that general recommendations from this group are not going to help us. We need some specific very, very hard-nosed recommendations and well thought out concepts in order that we can take the next step. Thank you very much.

Now we're ready to begin the detailed briefings on the programs that I spoke about this morning. The first speaker today will be Keith Potts who is representing Ray Alverez from Air Traffic. He's going to give us a base from which to work by explaining the kind of airspace associated with Air Traffic Control so that we can get our definitions straight.

AIRSPACE STRUCTURE AND AIR TRAFFIC CONTROL

Keith Potts and Hal Becker

Federal Aviation Administration

Thank you very much Ed, Air Traffic is supposed to be represented here today by Ray Alverez who asked me to express his regrets that things overtook him and he couldn't be here today. I have with me a group of people from the Air Traffic Service, Hal Becker for the Airspace Division and we have Frank Barron and Lew Butler from the Procedures Division, the AT-300 Division. We'll be around to answer any questions that we can for you.

I'm especially pleased to be here and given an opportunity to see a lot of old friends that I don't get to see everyday, and maybe I can make some new ones by meeting people that I've not had an opportunity to meet. I think that because I'm relatively new in the Airspace Division I've got a lot to learn and I'm hoping to do that today.

I'm hoping we can fill you in one the existing airspace structure as we were asked to do. What we plan to do is give you a brief overview of what controlled airspace is and the rules that govern flight in that airspace. And looking at the E & D Initiatives Report and hearing what was said this morning, I think that there are several rules on the books today that will have to be considered for change if we go through some kind of procedure which was outlined, because of the requirement of the meteorological restrictions that are in some of the airspace now. So I'm not even going to try to get into that. I'll ask Hal Becker from the Airspace and Air Traffic Rules Branch to take it from here and give you a brief overview. Thank you very much.

Thank you Keith. Good morning everyone. As Keith said, we're going to give you a brief run through of the existing airspace system and the procedures and the rules that apply - some of you are quite familiar with it I'm sure. It may be new information to others. To start it off and refresh your memories I'm going to use a slide, it's an illustration from the Airmen's Information Manual showing the airspace system's basic structure and you can follow along with that as I give the description.

To begin I'm going to talk about the uncontrolled and controlled airspace. Uncontrolled of course does not provide ATC services. In controlled airspace, there are several types, and the levels of ATC service vary. The uncontrolled airspace is shown as the shaded area on both sides of the slide there. It extends from the surface up to 14,500 ft. MSL or to the base of the overlying controlled airspace. In most of the Continental United States it terminates at 1,200 ft. above the surface or 700 ft. above the surface.

In the controlled airspace categories - I'll start with the control zone which is shown in the center there - it's indicated as a cylinder centered on an airport, has a five mile radius and extends from the surface up to 14,500 ft. and it can have extensions as they're shown to give it some type of a keyhole appearance to accommodate the instrument procedures for that airport. The airport traffic area that you see enclosed in the control zone exists at every field that has an operating control tower.

The next airspace we'll talk about is the control areas and transition areas, they are shown extending out away from the control zone and they also extend up to 14,500 ft. beginning at 1,200 or 700 ft. AGL. In the control zone, the control areas and transition areas, you can have a mix of controlled IFR traffic and some controlled VFR traffic. The next controlled airspace will be the continental control area which is shown as beginning at 14,500 ft. MSL and extending upwards. There is no upper limit on that airspace, and it covers the Continental United States and also most of Alaska.

Within the continental control area we have another type of controlled airspace and that's known as positive control area which begins at 18,000 ft. MSL and extends up to flight level 600, the arrow shows the jet routes which are designated from 18,000 ft. up to flight level 450. Any traffic above flight level 450 is on point-to-point navigation because there are no designated routes up there.

To that basic airspace structure there are two other types that we add; they're not shown on this slide. At an airport or terminal area where we have a significant amount of traffic we may wish to establish a terminal radar service area, or TRSA to increase the level of ATC services available. A TRSA would encompass

the control zone and extend outward. Although it's normally cylindrical in shape it can have various shapes. We have two levels of TRSA's or two levels of service provided in TRSA's. There's Stage Two and Stage Three service, and when I talk about ATC services I'll describe those.

If the airport is a major terminal and there is a significant volume of activity then we may wish to establish a Terminal Control Area or TCA. The TCA again is centered around the major airport, it always has shelves extending outward and extends up to 7,000 ft. or as high as 12,500 ft. MSL. The service provided in there is the highest level of service provided in a terminal area.

Now to get into the services provided. In uncontrolled airspace of course there is no ATC service. There can be IFR operations but they are not afforded any separation by Air Traffic Control. In the control zone an IFR aircraft is separated from other IFR aircraft. VFR aircraft can operate in good weather without contact with ATC. There can be a mix of controlled IFR and uncontrolled VFR. In the control areas the same situation can exist, IFR is separated from IFR,and VFR can be in there unknown to ATC. In most cases basic advisory service, traffic advisory service, will be provided to VFR aircraft who wish to participate and the traffic information is also given to IFR aircraft when it's desirable.

When we get to the Positive Control Area beginning at 18,000 ft. there is no VFR operation. All aircraft in accordance with the Instrument Flight Rules, the aircraft must be equipped and the pilot qualified for IFR - no VFR rules apply. Everything is controlled by ATC.

Now in the Terminal Radar Service Areas that I mentioned earlier which center around an airport, we have two levels of service; the Stage Two service that provides radar advisories, traffic advisory service, and sequencing service to participating aircraft. Of course, IFR aircraft in the TRSA are separated from each other, VFR aircraft are not separated although they can be sequenced and vectored at a pilot's request, but they are provided with traffic advisory service. In the Stage Three service that we provide in some TRSA's, those that have more traffic, we provide radar separation and sequencing to all participating traffic. That means that the VFR traffic that participates in the service is separated from the IFR. The separation standards are somewhat reduced but separation is provided, and all traffic is sequenced arriving at these major airports. I'd like to point out here that for VFR aircraft it is not mandatory that they participate in this service, in the terminal radar service area, it's voluntary on the part of the pilot. He can refuse the service and operate into the area or out of it without receiving the separation. He must, however, and here's where the airport traffic area comes into play, he must communicate with the control tower prior to entering the

airport traffic area. In that case that's the only requirement. Now in the terminal control areas where we provide a higher level of service all aircraft will receive ATC separation, both VFR and IFR aircraft. VFR aircraft are not permitted into the terminal control area without authorization from ATC.

As I've said, everything above flight level 180 is operating IFR and there is no mix of VFR traffic in that area. I'll run through the operating rules that apply in these various airspaces and let me try another slide that might help illustrate them a little better. First we'll go to the uncontrolled airspace. In order to operate VFR in uncontrolled airspace the pilot must have at least one mile flight visibility. If he's going to operate at less than 1,200 ft. above the surface he has to operate clear of clouds, there's no specified minimum distance, and that's shown on the little illustration on the right corner. Again staying in uncontrolled airspace above 1,200 ft. above the surface the flight visibility minimum is still one statute mile, however, the minimum distance from clouds now goes to 500 ft. below the clouds, 1,000 ft. above and 2,000 ft. horizontally. And that minimum applies up to 10,000 ft. MSL. Above 10,000 ft. you can see that the visibility, and this is also in controlled airspace, increases to five miles, the cloud distance minimum increase to 1,000 ft. below and 1,000 ft. above.

In controlled airspace the visibility minimums for VFR flight are three miles, as shown in the illustration of the control zone and also in control areas, three miles minimum flight visibility, cloud clearance minimums of 500 ft. below, 2,000 ft. horizontally and 1,000 ft. above. Above 10,000 ft. then in controlled airspace up to 18,000 ft. the visibility and cloud distances minimums are the same as they were for the uncontrolled airspace the 1,000 ft. above and below and one mile horizontal, five miles visibility.

Now there are rules that apply to operations in these airspaces, for the altitudes to be flown. They are referred to sometimes as the hemispherical rules and for aircraft not receiving ATC services or ATC separation they do provide a form of separation. In uncontrolled airspace above 3,000 ft. above the surface if the aircraft are operating under VFR and their magnetic course is from 0 or 360 degrees to 179 degrees then they fly at an odd altitude plus 500 ft. In other words if you were on a magnetic course of 090 degrees your altitude could be 5,500 ft. or 7,500 ft. For VFR aircraft headed in the other direction 180 degrees to 359 degrees their altitudes are even plus 500 ft. and that provides roughly 1,000 ft. separation between the opposite direction traffic. IFR aircraft which do not receive any ATC service in uncontrolled airspace use the same hemispherical rule, however, they don't add the 500 ft. to their altitude. In other words, the IFR aircraft operating on the Eastbound courses uses the odd altitude, and those operating on the Westbound courses use an even altitude. The hemispherical rules in controlled airspace apply only to VFR aircraft which use the same odd or even plus

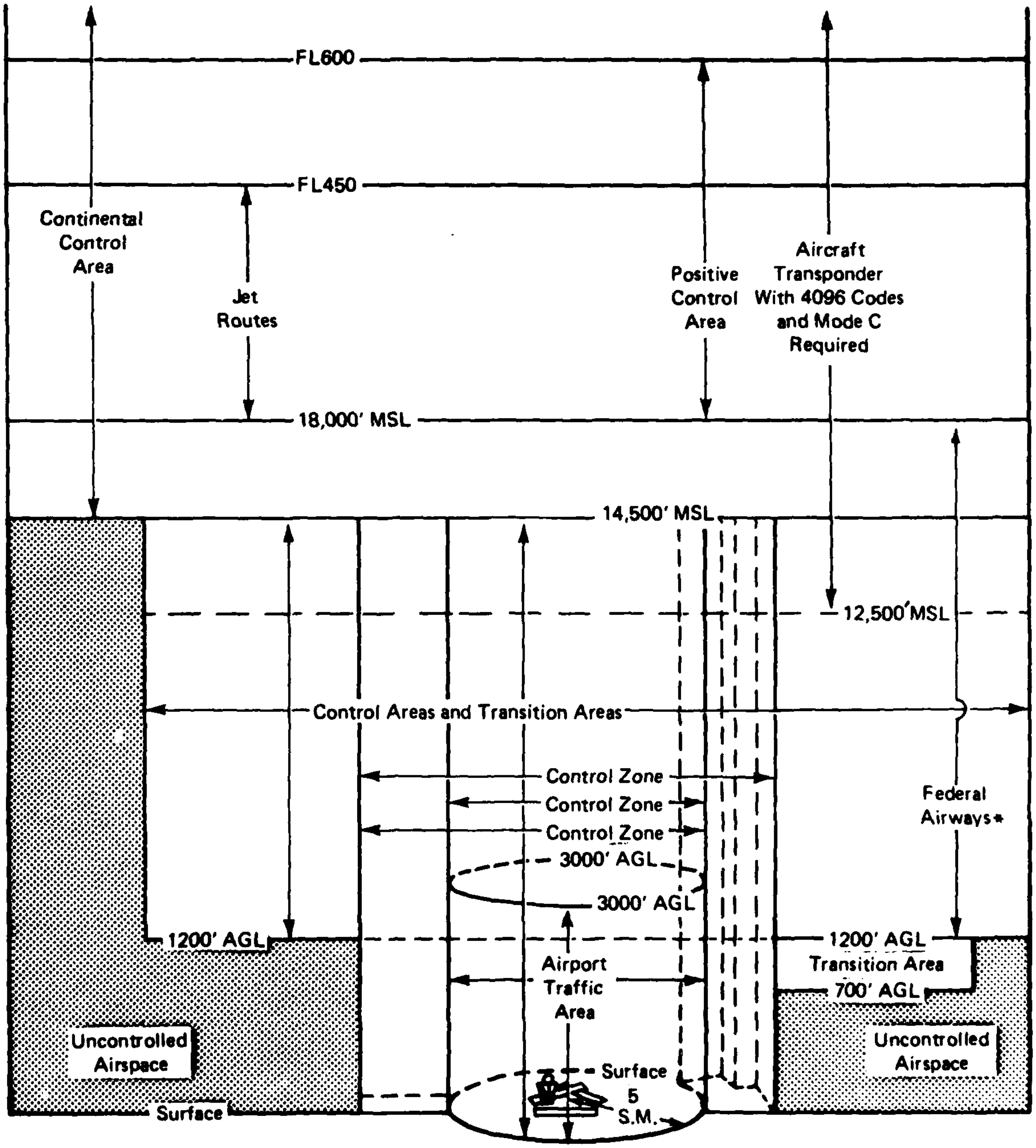
500 ft. IFR aircraft in controlled airspace are assigned an altitude by ATC, so there is no hemispherical rule in controlled airspace for IFR aircraft. ATC will assign an altitude that does not have that 500 ft. difference in there so you have essentially the same situation.

Another point to remember here, helicopters operating below 1,200 ft. above the surface can operate in that area with less than one mile visibility if they operate at a speed which allows them to see and avoid obstructions and other traffic.

I would like to cover the speeds because they are directly related to the see-and-avoid concept mix of controlled and uncontrolled traffic below 10,000 ft. There is a general speed restriction of 250 knots; no aircraft operating in excess of that speed below 10,000 ft. In the airport traffic area the speed restriction for reciprocating engine aircraft is 156 knots, for turbine powered aircraft 200 knots. Underneath the shelves of the terminal control area, because we expect that there will be some traffic operating down there to circumnavigate the TCA, there is a speed restriction of 200 knots.

There are also Transponder equipment requirements. Any aircraft flying above 12,500 ft. MSL is required to have a Transponder with the altitude reporting capability or Mode C. Any aircraft operating in a Group I Terminal Control Area, and I didn't mention that we have two types - we have Group I and Group II - the difference being the requirements. In the Group I the aircraft are required to have the Transponder with the Mode C. In the Group II just the 40[illegible] code Transponder is required, not the altitude reporting capability. In Group I the pilot is required to have at least a Private Pilot's License, and there are requirements for radio and navigational capability in both Group I and Group II.

That was a very fast and a very broad overview of the airspace rules and some of the services provided.


FL600
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Continental Control Area
Jet Routes
Positive Control Area
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18,000' MSL
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ELECTRONIC FLIGHT RULES

John W. Andrews

Lincoln Laboratory

Dr. Koenke has provided a very credible introduction to the Lincoln Study of the Electronic Flight Rules concept, and if I seem to be covering some of the same ground it's because it's important ground and it's necessary to understand the thought processes that have been followed in developing this concept. At the time this study was begun the Electronic Flight Rules idea was being discussed in rather general terms within Topic Group III of the E & D Initiatives process and we were attempting to put some flesh on the bones of the idea, to take all the possible ways in which you might conceive of doing EFR and to attempt to somehow order them so we could identify what the more promising avenues or promising approaches were. This was not with the idea that everything except the most promising idea should be totally forgotten, but with the idea that if we could at least come up with one credible way of doing EFR then perhaps the concept was something we should pay attention to and that people should listen to.

I'm going to talk a lot about problems with different ways of trying to do EFR and I hope I don't give the impression that EFR is nothing but problems. If we had yielded to the temptation to begin by advocating a particular system, we could have picked one and then stand here all day and talk only about its good points while ignoring its deficiencies. But it's very important to try to look at the implications of the system in all areas and to consider all feasibility criteria that might be applied to it, and in particular to consider the effect of the system upon users of the airspace other than those who are interested in EFR. You find when you do so that there are a lot of systems with very good points but with certain flaws that are very difficult to eliminate. And unless you are able to come up with a credible way of solving those particular problems, the system would be very difficult to implement.

I'm going to try to define more precisely what we mean by EFR, and to talk about some of the requirements that might be imposed upon the system. I'll talk about the surveillance aspect of the system, which is directly related to surveillance coverage. We'll talk about conflict rates, traffic densities, and how we'll resolve conflicts and then try to summarize what conclusions we were left with at the end of our study.

EFR has three primary attributes. First, it's a primary separation service - it's not just a back-up to somebody else's primary service. EFR is the first line of separation for aircraft that use it. Secondly, the EFR aircraft fly in an unconstrained manner. In other words, when you are not in proximity to other aircraft, you're under no constraint and you're following no clearance. This implies of course that EFR aircraft have considerable flexibility in selecting flight paths. Thirdly, in EFR no time-critical decisions are made on the ground by a human controller or other individual. This implies that the decisions that have to be made promptly are being made either by the pilots or by some kind of automated computer logic. We feel that you can achieve the goal of allowing pilots to fly in IMC with the same flexibility and freedom of flight that we attribute today to VFR flight under VMC conditions. And I might add that we were very interested in looking at systems that could be applied in low altitude airspace, because that's the area where we consider the payoff to be greatest for this kind of flight.

Just so the difference between EFR and other systems doesn't get blurred in your minds I'd like to point out that two other developing automated systems differ from EFR in two ways - important ways. ATARS is a back-up system; it's a Collision Avoidance System which waits for something to fail before it activates, whereas EFR is a primary system. The AERA system as it currently seems to be defined is a system which does use constraints. Either Flight Plans or clearances are constantly in effect and constantly constrain aircraft. In contrast, EFR flight is unconstrained except during conflicts when resolution is necessary.

Now how does EFR work? What would it be like to fly EFR? As implied by the name, electronics are very important to the concept. There are a number of possible electronic configurations of course; EFR could involve air derived data with surveillance done solely with avionics in aircraft. It could involve uplink of ground derived data from ground stations. In either case the net result is to provide the pilot in the EFR aircraft with either some instructions about how to stay separated

from other aircraft or else with information that enables him to avoid coming into close proximity. We might envision the following scenario in one situation. The pilot is flying VFR and suddenly encounters IMC conditions (which he probably has anticipated). He pushes some button in the cockpit or turns some knob and turns on his EFR unit. He then enters IMC with the approval of his EFR unit. After flying some period of time he encounters another aircraft which is also flying under EFR. Some resolution process is then activated and the two aircraft use the EFR system to maintain separation until they are clear of each other. If the aircraft subsequently leaves IMC and re-enters areas where VFR is possible the pilot may choose to turn off the EFR unti and complete his flight VFR. The important thing about this scenario is that when the pilot wanted to enter IMC he didn't have to file a Flight Plan, he didn't have to contact anybody, he didn't have to wait for processing of an approval from a manual system or system on the ground.

While there are obviously a lot of benefits to the user (as Dr. Koenke has touched upon) which might accrue if you could achieve this kind of flight, there are also benefits to the ATC system, one being to absorb growth in IFR traffic. A lot of anticipated growth in IFR aircraft handled is due to General Aviation IFR and Commuter Flights - both of which might be very interested in EFR. The other benefit is to reduce the per aircraft cost of Air Traffic Control. Apparently the cost of controlling smaller aircraft, in the manual ATC system, is a significant fraction of the total operating expense of such aircraft. If we could automate the control process we might be able to provide those small aircraft with a means of control that's more consistent with their total operating cost. There are many direct benefits for the users in terms of eliminating delays, direct routing, optimum climb (with associated fuel savings) and allowing a safer IFR flight in that the pilot who did not want to file IFR would not have to divert around most weather or be tempted to proceed in less than satisfactory visual conditions. It's important to recognize in talking about all the ways in which we might establish EFR it's very easy to conceive of systems that are technically viable but which can never be implemented because they violate certain principles which are widely adhered to in the aviation community. There are two principal feasibility requirements which we have come to regard as important to the design of the EFR system. We see these requirements reflected in many statements from the aviation community as well as past FAA rule-making and congressional testimony. I want to state these carefully.

The first criteria is that EFR must not prevent aircraft which so desire from operating in IMC with a level of safety which is at least as safe as IFR today. The motivation for this is that there are at least some users (scheduled Air Carriers come readily to mind) who would find it very difficult to accept other aircraft flying around in the clouds with them, if those aircraft were employing a mode of flight which degraded the achievable level of safety for all users. This doesn't say that two EFR aircraft have to be separated with the same level of safety they would enjoy if they were both IFR. But it does say that when an EFR aircraft and an IFR aircraft meet in the clouds there are special safety considerations that might not otherwise apply. If it turns out that we are fortunate enough to find an EFR system which is safer than current IFR, there is absolutely no problem on this score. The sticky question arises if we propose a system which is somewhat less safe than current IFR but still safe enough to be attractive to many users.

The second basic requirement is termed "non-exclusion". It says that aircraft with no special EFR electronics should be allowed to continue IFR operations in airspace in which EFR service is offered. One alternative to this is to require all IFR aircraft that want to operate after EFR is implemented to buy some special piece of electronics to interface with the EFR aircraft. In this case, getting the first EFR aircraft off the ground would be very difficult! The other alternative is to define mutually exclusive airspace in which conventional IFR operations are prohibited simply becuase EFR aircraft may be in that airspace. It's possible to do that of course, but when you begin to do so you impose an operational burden either upon the conventional IFR user or upon the EFR user or both. And obviously if you get to the point where large blocks of airspace are either prohibited for EFR or prohibited for conventional IFR you have operational problems. If EFR is really going to deliver significant benefits it must be implemented over a large enough area to make it attractive to operators to equip or qualify for EFR. If we have to fight to get IFR out of the airspace before we can get EFR in there are some real problems with implementing the EFR system. The remainder of my talk is going to focus primarily on systems which meet these feasibility constraints.

Now in order to understand about how we would go about mixing IFR and EFR it helps to think about how we mix two different flight modes today: conventional IFR and VFR. Under VMC conditions the VFR aircraft can see the IFR aircraft and vice-versa. Visual links enable each pilot to acquire and independently maintain separation (or at least to see what the traffic is doing). If we think about EFR flight under IMC, the situation is different. Under IMC the visual link is broken. EFR replaces it with an electronic link which allows EFR air-

craft to see that the IFR aircraft is there. But a question arises concerning reciprocity. How does the IFR aircraft know that the EFR is there? Does he even care? Does he have to know? Would it be acceptable to have a system in which the IFR aircraft was in conflict with another aircraft and simply wasn't informed of the conflict and had no idea that the other aircraft was trying to maintain separation? It turns out there are some problems that arise quite quickly when you enter such a mode of flight. An uninformed IFR aircraft can inadvertently negate maneuvers undertaken by an EFR aircraft in order to maintain separation. This is particularly critical if the IFR aircraft is higher performance. In that case anything the EFR aircraft tried to do might be cancelled. In order to maintain safety in such a situation the IFR aircraft would have to cooperate at least to the extent of not blundering in a way that would cancel the effect of the EFR maneuver. Therefore an EFR/IFR interface is required to provide some means of informing that IFR aircraft of what is necessary in order to allow separation to be achieved.

And now we come to the difficult question of how to establish that interface without requiring that IFR aircraft buy new equipment. Within surveillance coverage there is a rather obvious answer which seems to be basically feasible. It is to require the EFR aircraft to communicate with the ground, and provide maneuver intent to the ATC controller who is responsible for the IFR aircraft. Within surveillance the controller can see the position of both the EFR aircraft and the IFR aircraft. This way the coordination can take the place on the ground in such a way that the IFR pilot receives clearances which are consistent with what the EFR aircraft is doing. To the IFR pilot the EFR system is transparent; he's simply following the same IFR procedures he has always followed. The additional coordination work is done on the ground by a human controller or (in the future) by systems like AERA.

If you think about what happens outside surveillance coverage the problems are quite different and much more difficult to resolve. In this case, EFR/IFR co-existance requires some direct interaction between the aircraft because ground ATC doesn't know where the EFR aircraft is and perhaps doesn't even know how many EFR aircraft are out there. The only way that coordination can be achieved is to require that the IFR aircraft carry some sort of equipment that interfaces with EFR. This of course violates one of the criteria that we have imposed, namely that the system not require that the IFR operator buy special equipment to interface with EFR aircraft. I should also add that the cost and the technical challenge of doing EFR using an airborne mode are also greater. At the current time (at least at the completion of this phase of the study) we are rather discouraged at the prospects for extending EFR outside ground surveillance coverage because of the problem of ensuring

compatibility between IFR and EFR. We have concluded that a lot more development of air-to-air surveillance techniques is required in order to make such an operation promising.

I'd like to make another point about equipage that may already have occurred to you. If the EFR aircraft has to be able to detect non-EFR aircraft then the only electronic alternatives are those using beacon-based surveillance: that's the only type of surveillance which is currently in the cards for aircraft operating without EFR. This leaves us with certain surveillance alternatives that are fairly familiar to most persons present. One is an ATCRBS surveillance system; another is a BCAS type of surveillance, and another is DABS. These three alternatives were looked at in further detail during the study. The ATCRBS system has some potential technical difficulties with the quality of surveillance data and also has difficulties in establishing a reliable communication system. We looked at a system which would use a voice synthesizer to communicate with ATCRBS equipped aircraft without a digital data link. We concluded that there were some significant problems in maintaining the correct association between the aircraft's track in the surveillance system and the call sign or identity of the aircraft in the data link system. It would require modification of ATCRBS sites if we were to take advantage of existing sensor coverage. And by the time you finished upgrading ATCRBS sites to the standards that are required, it would be almost as easy to go ahead and install a DABS at the sites.

BCAS at first glance might offer the prospects of operating outside coverage, but recall that in order to coordinate with IFR we are restricted to systems which can operate properly within the coverage. There is also a question of an increased range requirement, in that while a collision avoidance system can operate at the very last instant at close range, a primary system has to reach out somewhat further. The greater the range required of the surveillance, the more difficult it becomes to do with the BCAS type of surveillance. Furthermore, in view of the probable cost of these types of units, one begins to ask questions about how widely EFR equipment would be used.

DABS is a system that was designed to support tactical air traffic control; the surveillance and communications capabilities are really not seriously in question regarding use of DABS for EFR. The problem with DABS is that coverage is limited by DABS sensor deployment. You only get coverage where you put in DABS sites. Since it takes a while for DABS sites to be deployed, the issue is the number of DABS sites needed in order to make EFR viable. We looked at this question by drawing coverage maps, rather simplified drawings, in which the coverage of a sensor at a given altitude was represented by a circle determined by the elevation cutoff, line-of-sight. The figure provides a map for 6,000 ft. above ground level for a hypothetical network of 123 DABS sensors. I understand now

that the initial deployment of DABS is going to be something like 93 sensors, so this probably approximates the initial DABS deployment. The coverage is good but there is a lot of redundant coverage in areas where you have a lot of traffic, namely in the Northeastern U.S. and Southern California. There are big gaps in the coverage in some of the Western States and gaps appear in the South Central areas. The problem with gaps for EFR is that if you wanted to fly from say, Chicago to Houston and there is a gap in the VFR service and there happens to be IMC weather in that gap, you would have to file IFR just to get through that little gap. It's obvious that the total benefits that could be derived are limited by coverage.

However, because most IFR traffic is where most of the sensors are located, you can cover a large fraction of IFR operations even with the limitations of a ground based sensor network. One solution to filling coverage gaps is to fly at higher altitudes where the circles become larger and coverage is more extensive. There is a minimum cruise altitude that is required to achieve coverage in areas where the sensors are far apart. Another approach would be to try to put in gap-filling sensors. If we were allowed to pick a few sites strategically we could fill in the gaps in those areas without significantly adding to the total DABS deployment.

But to achieve full benefits with the ground-based system, i.e., to achieve total area coverage over the entire United States, you would have to come up with some alternative that operates outside coverage. Another thing that might limit your service is conflict rates. A tactical control system doesn't order the flight paths of traffic and in some density you obviously would want to impose order upon the traffic and not let people chose their own flight paths. In order to get a feel for the traffic densities that might occur enroute we looked at actual data tapes collected by the Lincoln Laboratory Transportable Measurements Facility (TMF) at several sites as well as the LA Basin traffic model. At all the sites that we looked at we found out that the enroute densities are quite low compared to the density at which tactical control might fail. Densities tend to fall off very rapidly away from traffic hubs. Once you get out to the enroute airspace the EFR conflict rate, even under the worst case of an aircraft flying at the altitude of greatest traffic density, is less than two conflicts per hour which is well within the range at which tactical control is feasible.

As an EFR aircraft flys into a TCA or into a traffic hub there is some period of time in which he is in a high density area but it is a very brief exposure which persists for only a

few minutes before the transition to Approach Control or before entering the TCA. The number of conflicts which occur during this period is actually quite small. Our general conclusion was that there is plenty of airspace up there for tactical control to work.

I want to touch now briefly on the characteristics of the resolution process. Once you know where conflicting aircraft are located you can proceed to decide what to do about it. Dr. Koenke has already mentioned that one of the questions is whether you use autonomous resolution or coordinated resolution; that is, does each pilot decide independently what he wants to do, or must pilot's coordinate their actions. There are a number of reasons (that are discussed in more detail in our report) why we think that coordinated resolution is a good idea. One is that you need it anyway in IFR/EFR encounters. Another is that autonomous resolution is probably going to be much more difficult under EFR conditions than it is under VFR. VFR resolution consists quite often of simply watching the traffic until he gets close enough to decide that he's no factor. If he does get close there is instanteous feedback should the aircraft maneuver (you see the wing dip). The closer the aircraft gets the easier it is to determine what he is doing. Under EFR you have limitations imposed by electronics. You have the problem of the limited accuracy of the data and the lag in detecting velocity changes. If the pilot is attempting to resolve by reference to a cockpit display, he must separate the relative motion of the aircraft from the actual translational motion. All of this makes resolution more difficult, imposes significantly increased workload upon the pilot, and results in less efficient resolution. For autonomous resolution, pilots have to start sooner to resolve, they have to maintain greater separations and they have to watch very carefully to make sure that the other pilot isn't doing something which negates the effect of the resolution strategy that they are attempting to implement.

One of the other significant questions concerning resolution is the extent to which decisions are made by the pilot and the extent to which decisions are made by computer systems. Henceforth we will assume no matter how decisions are made, some type of coordination takes place between aircraft. Now consider the advantages and disadvantages of having pilots make all resolution decisions. One advantage and a very important one, is that when pilots are involved intent can be utilized. Pilots know what they want to do, they know if any special conditions exist, and they can seek a resolution which reflects these considerations. There also exist a number of disavantages or at least problems that have to be worked through. One is that pilot based decision making might not always be practical. For instance, what if there are three aircraft involved in a conflict. How do you coordinate that situation on a pilot-to-

pilot basis? Also, if the pilot is busy he may not be able to devote the time needed to study the conflict situation. He may want to refuse responsibility. If you believe that there are situations in which the pilot can't resolve them you probably have to build an automatic mode into the system. Then you face the problem of deciding when the automatic mode takes over from the pilot and whether or not you can effect that transition.

The workload question has to be looked at. The pilot has to be well informed about what's happening prior to the time he actually begins to effect any maneuver that is required for separation; this means that he has to study the displayed information before the need for resolution is obvious. He may be forced to communicate with aircraft that come nearby in order to make sure that he knows their intent; the resulting communication load could be burdensome in some cases. He also has to monitor very closely what the results of any decisions are. The required display and communications capabilities increase when you want to give pilots enough information to make proper decisions. It is quite possible that you would need a graphic traffic display in order for pilots to maintain separation. A more capable communications system is required for providing instantaneous air-to-air communications on a clear channel. There is also a question of how to achieve cooperation and standardization since pilots may not agree on how a particular conflict should be resolved. There are many reasons why they might not agree such as the displayed situation looking different to each pilot. Or perhaps there is a situation in which a pilot can do something which is personally advantageous but which imposes a penalty upon his traffic. Pilots also have widely differing backgrounds and different levels of familiarity with the local air traffic control environment, all of which may result in some difficulty in agreeing upon exactly who should have the right of way or how things should be done.

I'm going to talk now about decisions by computer. There are certain advantages to this system; one is that the separation actions chosen are always coordinated and timely. There is essentially only one decision-maker involved and a coordinated set of instructions can be guaranteed to occur at the time that they are needed. There is no workload for the pilot prior to resolution - he doesn't have to talk to anyone or to even notice the exact details of how the encounter arose. There is also a minimal workload monitoring <u>during</u> the encounter. A computer based system could distribute and attempt to minimuze the burden of resolution by not requiring one aircraft to give way all the time or one aircraft to deviate significantly from course, but to provide an equitable distribution of the burden or resolution.

The disadvantage of computer resolution, and it may be a very significant one, is that the computer lacks intent; it doesn't know exactly what the pilots want to do, and it has to make an assumption about what they want to do in order to select an acceptable resolution. The most likely assumption that it can make is that in the near future aircraft wish to continue doing what they've been doing in the recent past. That is, if you're flying level at 6,500 ft. then what you want to do is continue to fly level at 6,500 ft. If the computer is right, then perhaps it can find a solution which doesn't require you to do anything other than what you wanted to do anyway. If it is wrong it may delay the aircraft or force a deviation from the intended path.

In searching for a way of combining these concepts (pilot-based vs. computer-based) to try to achieve the greatest number of advantages and the fewest number of disadvantages, we described a system which borrows somewhat from both approaches. First of all we've suggested that computer logic should generate coordinated instructions when aircraft come into conflict. This guarantees the safety aspect of the system. It also takes care of situations where pilots are unable to spare the time required to resolve or unable to come to an agreement about what should be done.

This system should use minimum constraints. By this I mean that the instructions that are generated should constrain the aircraft only to the minimum extent necessary to guarantee separation. There are two degrees of freedom available for maintaining separation - horizontal and vertical. When the system specifies actions which maintain vertical separation, pilots should be free to do anything they want horizontally. Similarly, use of horizontal resolution should provide freedom for pilot selection of altitude. The other thing the system should do is to assign blocks of airspace; that is, rather than telling a pilot to fly at 6,500 ft., constrain him only to fly above 6,500 ft. while his traffic is constrained to fly below some other specified altitude. Again this allows the pilot, even during a conflict, to choose from a number of flight paths the one which might be most desirable.

Secondly, the system should only deviate one aircraft from its flight path at a time. It turns out that this is quite possible in almost every encounter if you start at the right time. The result of these minimum constraint techniques is that a pilot can be in many encounters before he gets into one in which the system asks him to do something that he didn't intend to do, or that results in significant deviation from his intended flight path. We simulated a logic which attempted to implement this minimum constraint approach and found out that for the limited simulation data (about 100 encounters) it looked very promising. Thirdly, we recommend that the system should allow pilot inputs to the logic. This means that if the resolu-

tion that the automatic system has imposed isn't to the liking of the pilot, there should be a provision for the pilot either suggesting some alternative solution or providing the system with the information that it needs to recompute the solution and come up with one that is acceptable. We feel that this would be a refinement of EFR and not a necessity for EFR to work. Aircraft or pilots who want to participate with this kind of input should be provided the opportunity to do so.

The suggested resolution approach can be summarized as follows: When an encounter arises, the first thing that happens is that an automated logic guarantees safety by generating a solution which seems to be minimally constraining and which guarantees that the aircraft are safely separated. If it turns out that that solution is burdensome to either pilot, the pilot can inform the system of that fact and an attempt to find an alternative solution can be initiated. In some cases the EFR system may be unable to find a solution which is convenient for the pilot, but the fact that the conflict rates are low is one of the factors that decreases the frequency at which such situations occur.

To summarize the conclusions of our study - there are significant benefits both to the ATC system and to the user that could potentially be derived from EFR. We impose two restraints which we felt were justifiable and we focused upon systems which were implementable within those constraints. The most promising approach identified thus far is to use DABS for surveillance and communications and computer resolution logic. This is the approach that has the fewest problems to be solved before implementation.

There are areas that need further investigation, some of which we were able to devote some little time to. One such area is the EFR interaction with Air Traffic Control. How would the controller feel about having two EFR aircraft and five IFR rather than seven IFR in his sector? How do we communicate to Air Traffic Control what the EFR system is doing? What about the phase of flight in which the pilot has finished the enroute portion flying EFR and now wants to enter the terminal control area? How do we effect that transition efficiently? What is the level of benefits (in dollars and cents or in terms of delay saved) that can be derived from EFR? This depends upon how widespread EFR equipage is, and exactly how efficient EFR is in terms of allowing freedom of flight and flexibility of operation.

Finally there are system configuration alternatives or perhaps auxiliary approaches that might deserve further consideration. We would like to find a system which would allow us to operate outside coverage, but as I mentioned we are not encouraged about that prospect.

And finally there may be alternative modes of flight which compliment the basic EFR mode. EFR may be a multi-mode system and in fact in order to accommodate all users equitably it is quite possible that we will have to define additional modes of flight. Hopefully this conference, in addressing these issues, will advance our understanding of the problems significantly. Thank you.

ELECTRONIC FLIGHT RULES

AN ALTERNATIVE SEPARATION ASSURANCE CONCEPT

JOHN W. ANDREWS

WALTER M. HOLLISTER

MIT LINCOLN LABORATORY

7 JANUARY 1981

OVERVIEW

- EFR DEFINITION
- BASIC REQUIREMENTS
- SURVEILLANCE ALTERNATIVES AND COVERAGE ISSUES
- CONFLICT RATES AND TRAFFIC DENSITY
- CONFLICT RESOLUTION ALTERNATIVES
- SUMMARY

ELECTRONIC FLIGHT RULES

- A PRIMARY SEPARATION SERVICE IN IMC/VMC
- FLIGHT UNCONSTRAINED EXCEPT DURING CONFLICT
- NO TIME-CRITICAL DECISIONS BY HUMAN ON GROUND

COMPARISON OF EFR TO OTHER SYSTEMS

ATARS

ATARS IS BACKUP, EFR IS PRIMARY

AERA

AERA USES CONSTRAINTS

EFR IS UNCONSTRAINED

POTENTIAL BENEFITS OF EFR

ATC SYSTEM BENEFITS

- ABSORB GROWTH IN IFR TRAFFIC
- REDUCE "PER AIRCRAFT" CONTROL COSTS

USER BENEFITS

- ELIMINATE IFR CLEARANCE DELAY
- DIRECT ROUTING AND OPTIMUM CLIMB
- ALLOW SAFER NON-IFR FLIGHT

FEASIBILITY REQUIREMENTS

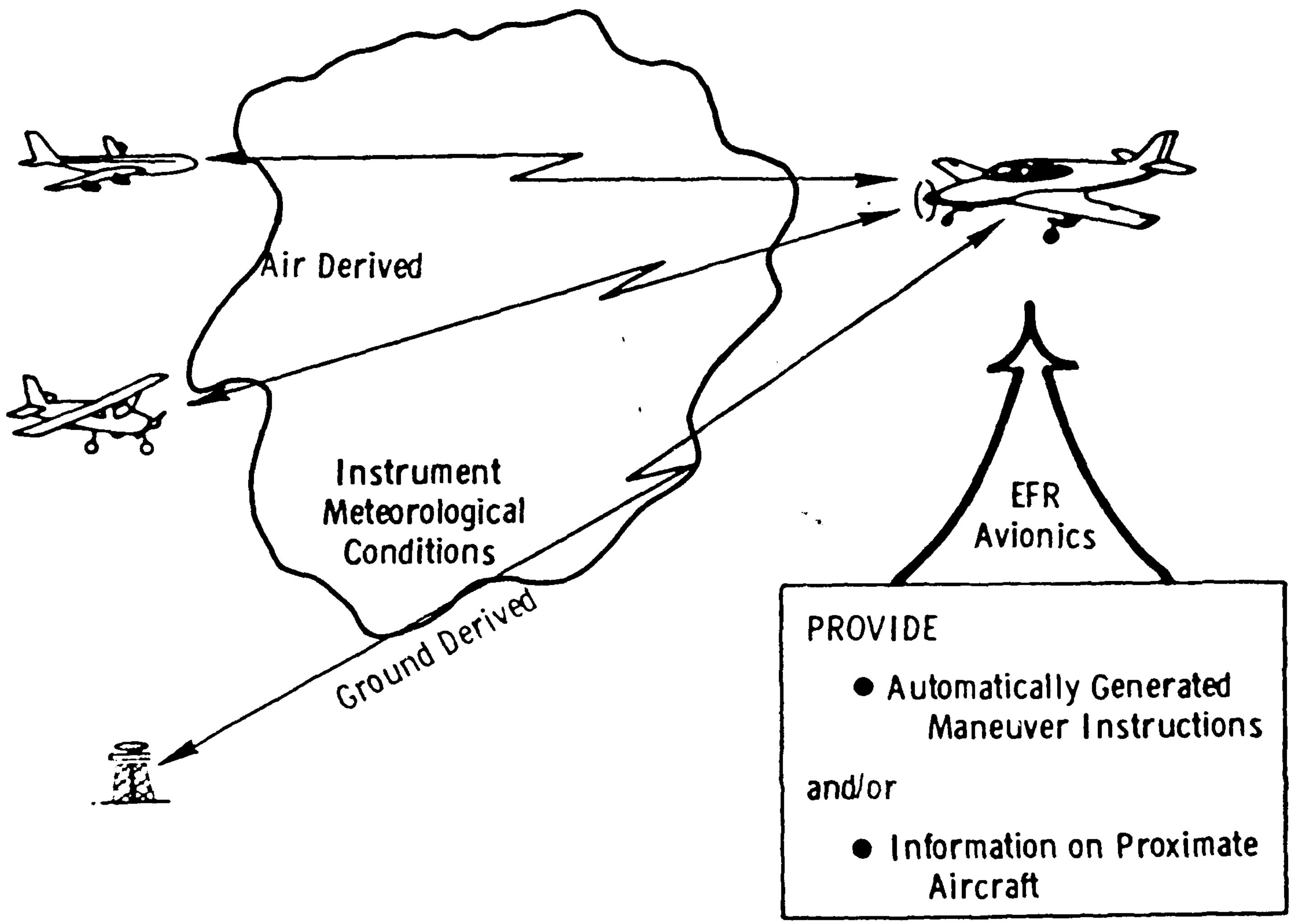
- PRESERVATION OF IFR SAFETY

  EFR MUST NOT PREVENT AIRCRAFT WHICH SO DESIRE FROM OPERATING IN IMC WITH A LEVEL OF SAFETY WHICH IS AT LEAST AS SAFE AS IFR TODAY.

- NON-EXCLUSION

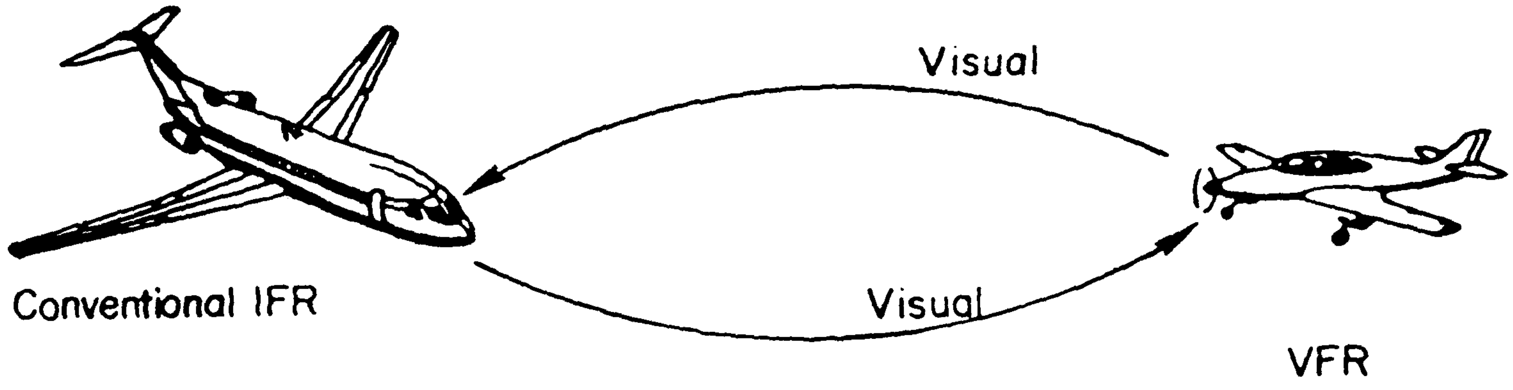
  AIRCRAFT WITH NO SPECIAL EFR AVIONICS SHOULD BE ALLOWED TO CONTINUE IFR OPERATIONS IN THE AIRSPACE IN WHICH EFR SERVICE IS OFFERED

ELECTRONIC FLIGHT RULES (EFR)



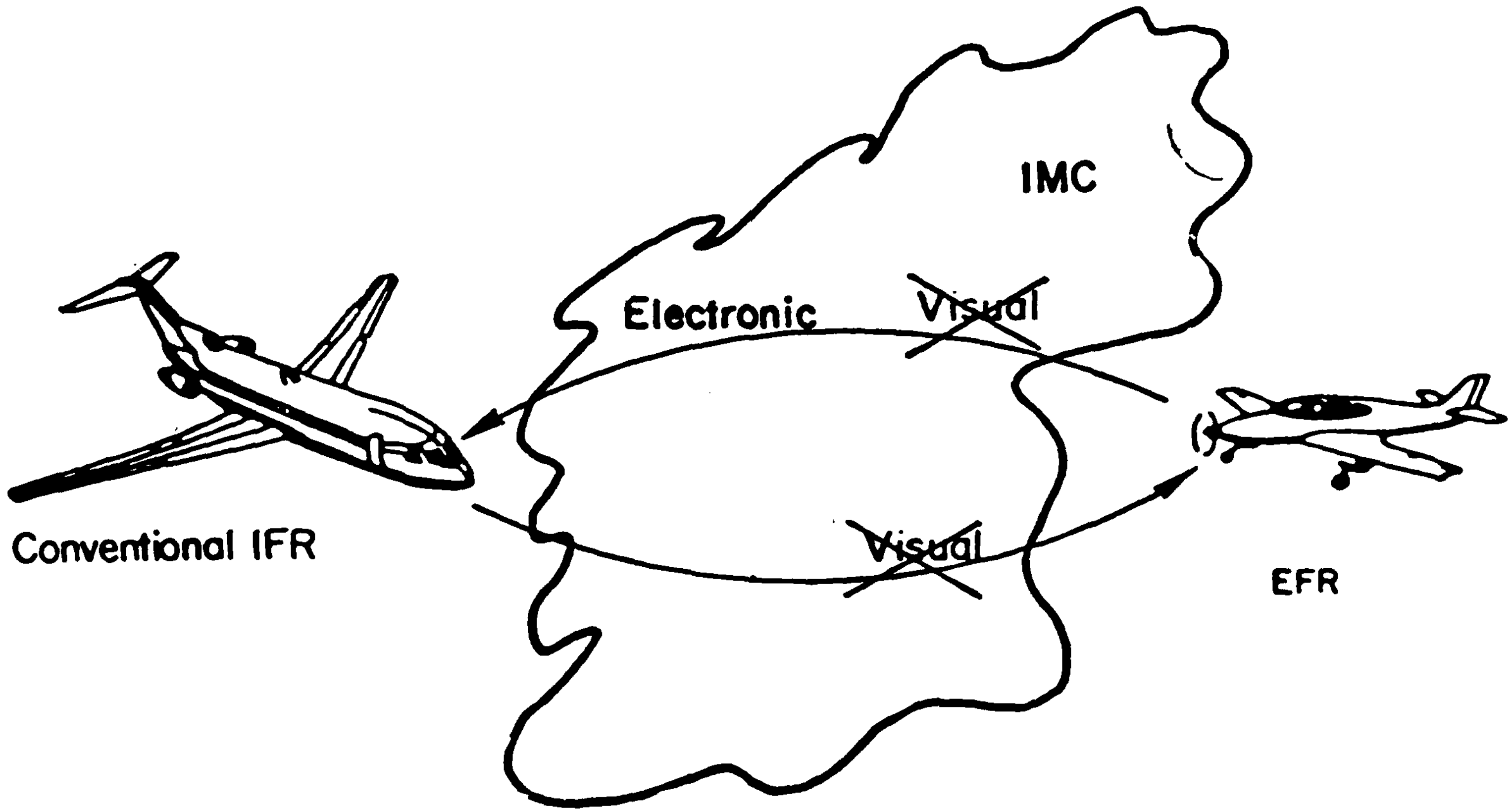
COMPATIBILITY WITH CONVENTIONAL IFR

The Question Of Reciprocal Protection



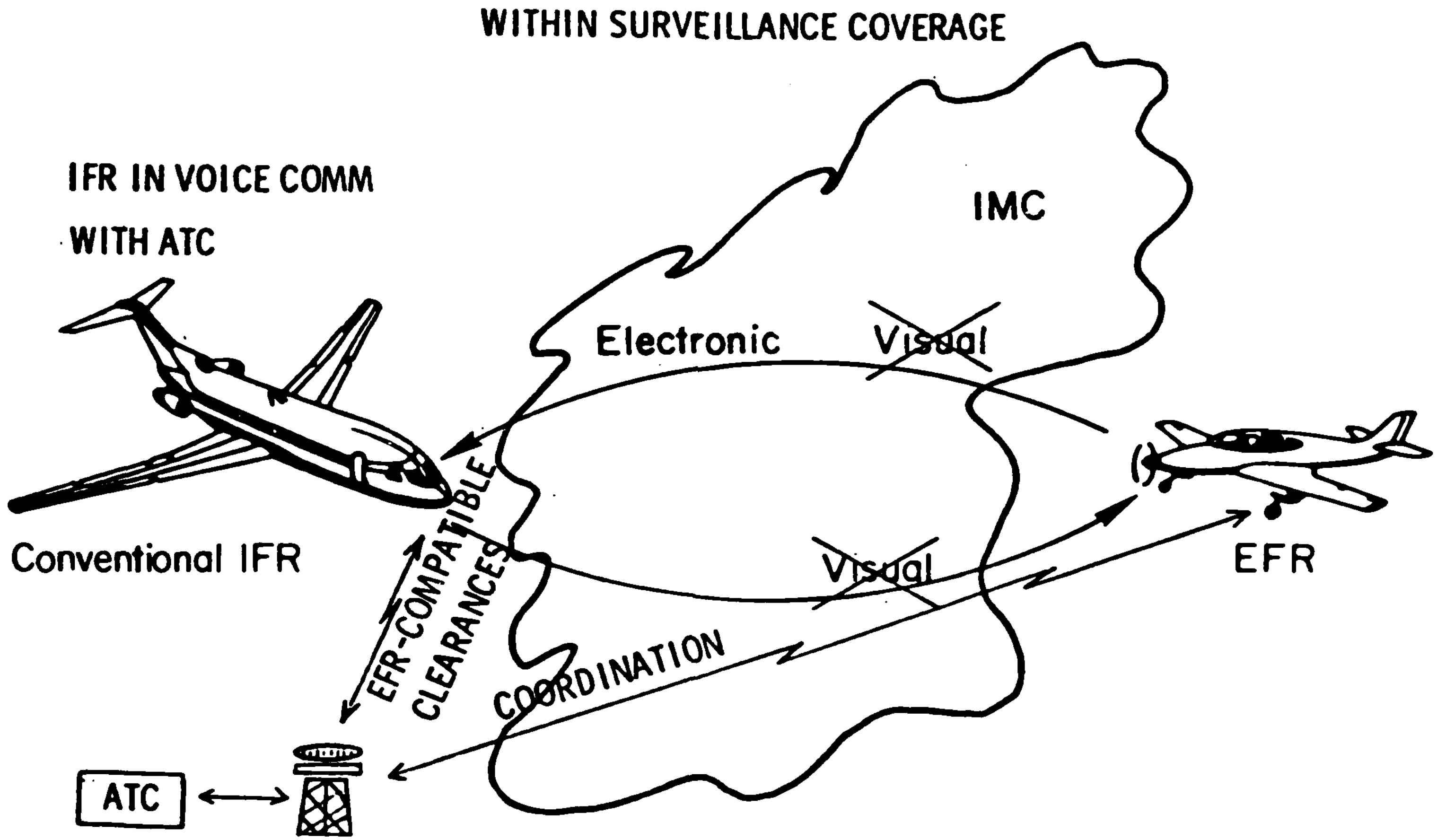
COMPATIBILITY WITH CONVENTIONAL IFR

The Question Of Reciprocal Protection



COMPATIBILITY WITH CONVENTIONAL IFR

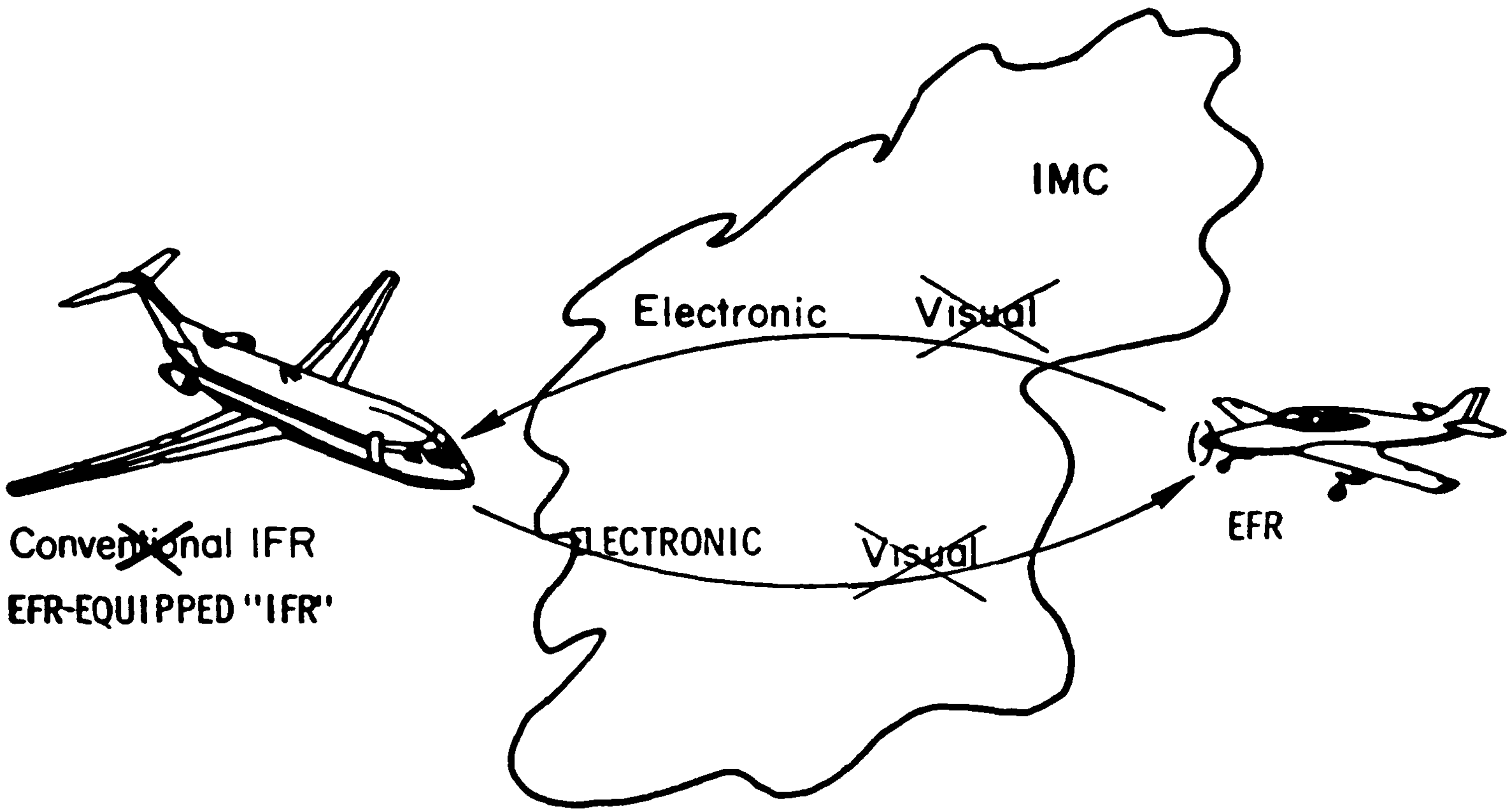
The Question Of Reciprocal Protection



COMPATIBILITY WITH CONVENTIONAL IFR

The Question Of Reciprocal Protection

OUTSIDE SURVEILLANCE COVERAGE



SURVEILLANCE TECHNIQUES

<u>IF</u>

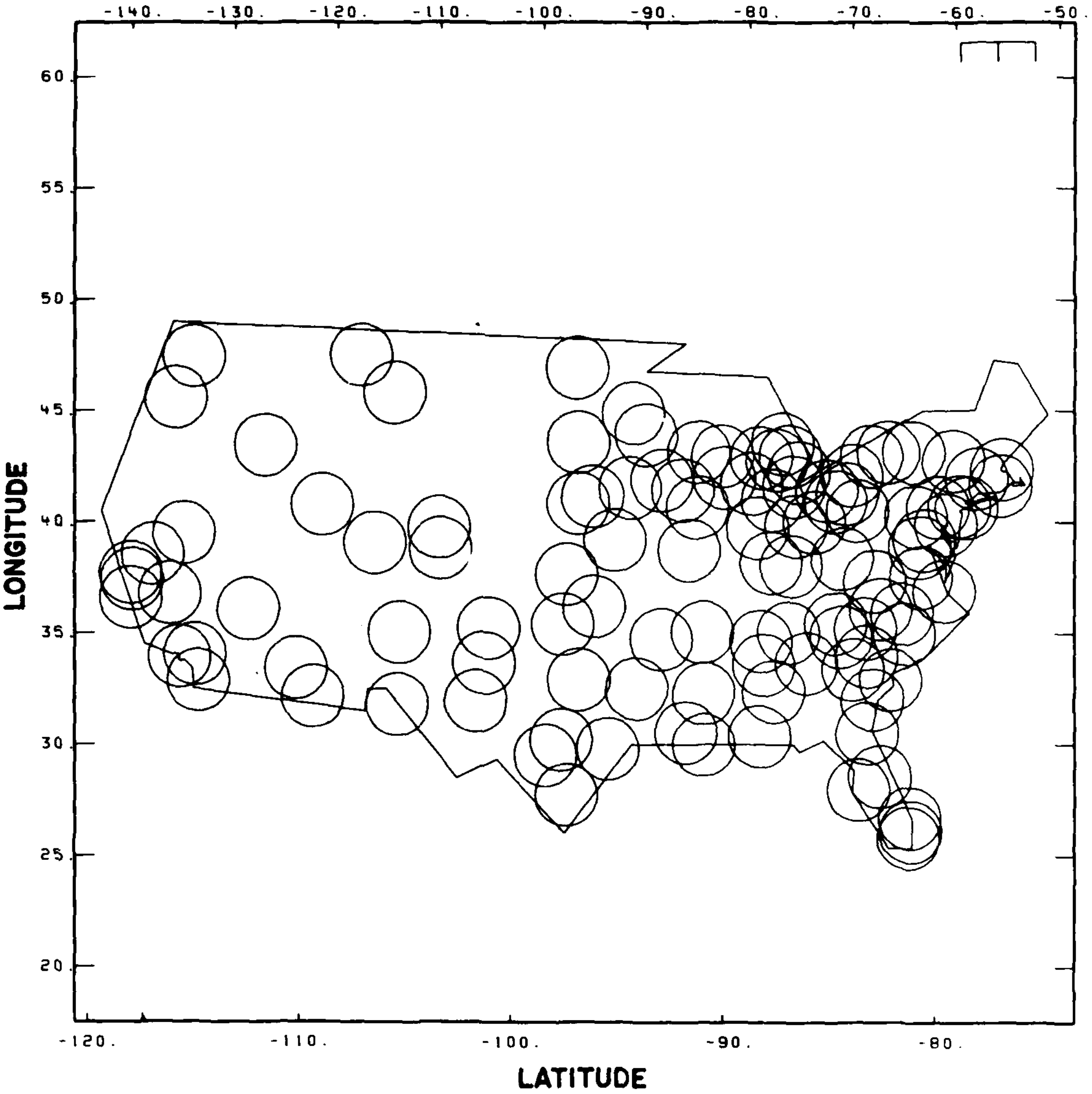
EFR MUST BE ABLE TO DETECT NON-EFR AIRCRAFT

<u>THEN</u>

BEACON-BASED SURVEILLANCE IS REQUIRED

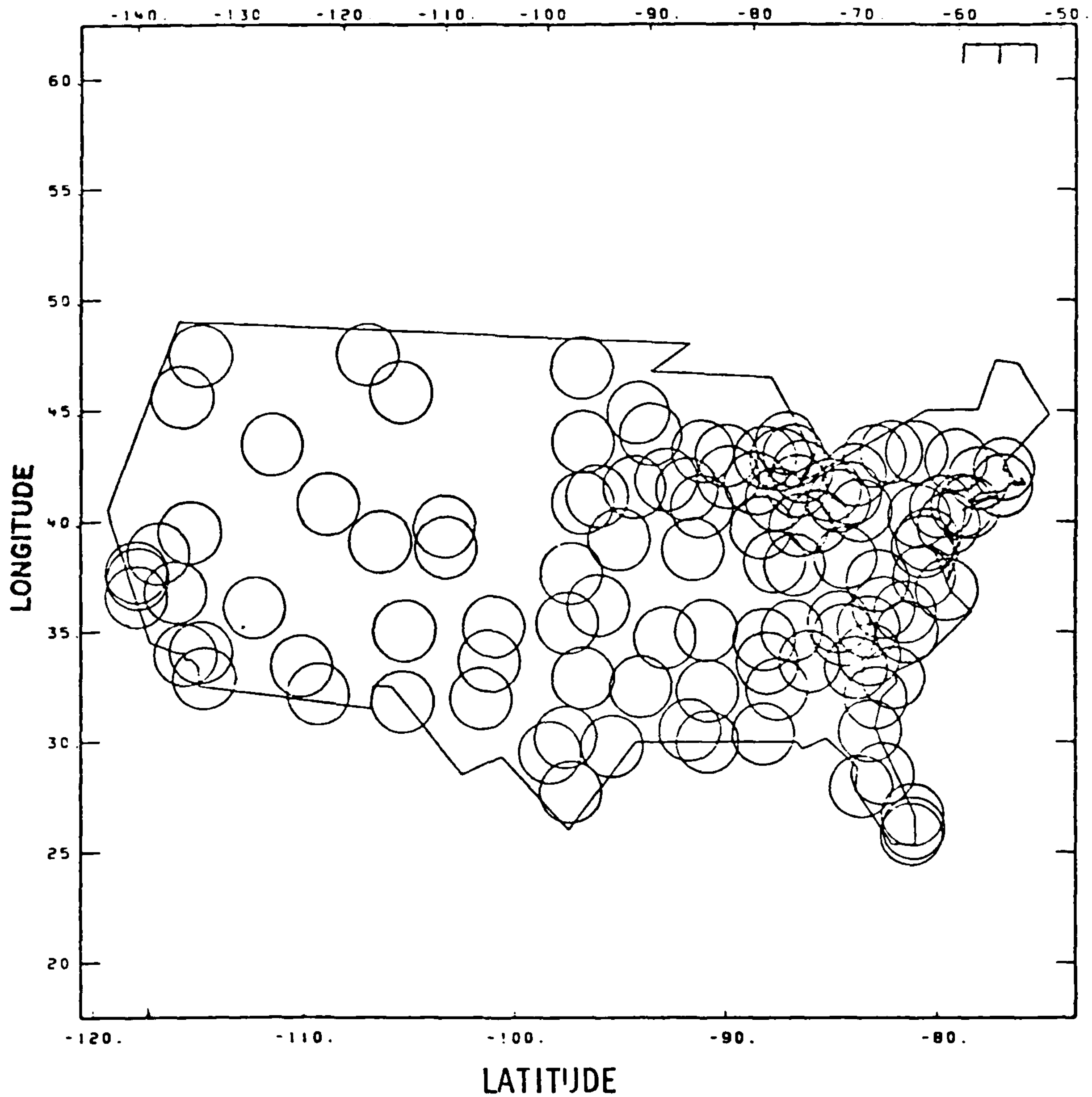
SAFETY CONSIDERATIONS IN EFR/IFR CONFLICTS

- UNINFORMED IFR AIRCRAFT CAN NEGATE MANEUVER BY EFR AIRCRAFT
- TO MAINTAIN SAFETY, IFR AIRCRAFT MUST COOPERATE IN RESOLUTION
- EFR/IFR INTERFACE REQUIRED



Radar coverage at 6000 feet AGL for 113 sensor nerwork.

RADAR COVERAGE AT 6,000 AGL - 113 SENSORS



CONFLICT RATES

- TRAFFIC DENSITY TYPICALLY DECREASES BY 1/2 FOR EACH 14 MILES FROM CENTER OF TRAFFIC HUB
- EFR CONFLICT RATE LESS THAN 2/HOUR AWAY FROM HUBS
- EFR AIRCRAFT MAY HAVE 1 OR 2 CONFLICTS AS THEY PASS THROUGH HIGH DENSITY AREA SURROUNDING HUB

AUTONOMOUS CONFLICT RESOLUTION

- INCOMPATIBLE RESOLUTION MANEUVERS MAY BE SELECTED
- PILOT WORKLOAD IS INCREASED
- INEFFICIENT RESOLUTION RESULTS

DECISION-MAKING BY PILOTS

<u>ADVANTAGES:</u>

- INTENT CAN BE UTILIZED

<u>DISADVANTAGES:</u>

- NOT ALWAYS PRACTICAL
- WORKLOAD ISSUE
- INCREASED DISPLAY/COMM COMPLEXITY
- COOPERATION/STANDARDIZATION QUESTIONS

DECISION-MAKING BY COMPUTER

<u>ADVANTAGES:</u>

ALWAYS COORDINATED AND TIMELY

NO WORKLOAD PRIOR TO RESOLUTION

DISTRIBUTES AND MINIMIZES BURDEN OF RESOLUTION

<u>DISADVANTAGE:</u>

LACK OF INTENT

EFFICIENCY IN TACTICAL RESOLUTION

- MINIMUM DEVIATION FROM PROJECTED FLIGHT PATH
- ONLY ONE AIRCRAFT DEVIATED FROM COURSE
- MINIMUM CONSTRAINT (E.G., "TURN RIGHT OF 240 DEGREES" OR "REMAIN ABOVE 6500 FEET"
- FREEDOM TO MANEUVER IN UNCONSTRAINED DIRECTIONS

A PROMISING APPROACH

- COMPUTER LOGIC GENERATES COORDINATED INSTRUCTIONS
- MINIMUM CONSTRAINT UTILIZED
- ALLOW PILOT INPUTS TO LOGIC

AREAS FOR FURTHER INVESTIGATION

- EFR INTERACTION WITH ATC
- EN ROUTE/TERMINAL TRANSITION
- LEVEL OF BENEFITS
- ALTERNATIVE/AUXILIARY APPROACHES

DABS, BCAS AND ATARS

Clyde Miller

Federal Aviation Administration

Good morning. My talk describes the principal elements of FAA's Aircraft Separation Assurance, or Collision Avoidance System. My talk focuses on those elements which display traffic advisories and collision avoidance resolution advisories directly to pilots as opposed to the elements which display advisories only to Air Traffic Controllers. The Discrete Address Beacon System (DABS) will be described briefly and its role in Collision Avoidance will be defined.

ASA (Collision Avoidance) SYSTEM

The objective of the Separation Assurance System is to provide a back-up for the conventional Air Traffic Control System that substantia-ly reduces the risk of mid-air collisions. The principal elements of the Separation Assurance System discussed in this paper, are ATARS and BCAS, pilot-oriented elements in the sense that their primary responsibility is to warn pilots of collision hazards and to recommend aircraft maneuvers that can be used to avoid mid-air collisions.

Conflict alert and conflict resolution are controller oriented elements that warn controllers of hazardous encounters. Conflict alert identifies aircraft in conflict on controller displays and is currently operational throughout the enroute airspace under radar surveillance and in the major terminal areas. Conflict resolution will extend the capability of conflict alert by providing controllers recommended aircraft maneuvers for resolving encounters.

Conflict alert and conflict resolution are not described in any detail here.

SYSTEM REQUIREMENTS

In order for a system to provide a viable separation assurance service, it must meet a number of requirements.

1. Operation of the system must be fully integrated and compatible with the existing ground-based Air Traffic Control System.

2. The system must be capable of issuing traffic and resolution advisories to users operating under either Visual Flight Rules or Instrument Flight Rules.

3. It must offer protection in all airspace, including airspace not covered by ground-based primary or secondary surveillance radar systems.

4. The elements comprising the system must interface with each other and must operate in a compatible, mutually supporting manner.

5. The system must not generate a large number of unwanted alerts (alarms occurring when no unsafe events have occurred.)

6. The system must not miss alerts or fail to provide warnings on potentially dangerous threats.

7. It must be capable of resolving encounters involving more than two aircraft. And finally,

8. Protection must be available to the first users who purchase the appropriate equipment. That is, equipage of a significant portion of the fleet with new avionics should not be a prerequisite for protection of participating aircraft.

In order to fully meet these system requirements, an integrated architecture consisting of four principal elements has been defined. Two of these elements, the Automatic Traffic Advisory and Resolution Service (ATARS) and the Beacon Collision Avoidance System (BCAS), are the pilot-oriented services of particular interest here. The remaining two elements are conflict alert and conflict resolution.

SYSTEM FUNCTIONS

Any pilot-oriented equipment intended for Collision Avoidance service in accordance with the preceding requirements must perform several well-defined functions.

The first of these functions is surveillance. The equipment must be capable of detecting and tracking aircraft to derive reliable estimates of relative ranges and relative altitudes together with their rates. Relative range and altitude data are sufficient to provide a collision avoidance service that operates only in the vertical plane (issues only climb/descend resolution advisories). If turn advisories are to be issued, aircraft bearings and headings are also required.

The second function is threat detection. Given tracked positions of proximate aircraft, the equipment must reliably determine which aircraft pairs are involved in hazardous encounters. Among those encounters classified as safe by the threat logic, there will be some which could become hazardous if aircraft maneuvered in the wrong directions. For these encounters, the equipment should be capable of issuing a traffic advisory to the pilot indicating the position of the nearby aircraft and, perhaps, the degree of collision risk it represents. Encounter pairs that are classified as hazardous are passed on to the threat resolution logic.

The third function is threat resolution. Given a hazardous encounter, a maneuver (or resolution) advisory must be generated for all aircraft that are equipped with collision avoidance equipments. If two or more of the aircraft in the encounter are so equipped, the resolution advisories must be coordinated among these aircraft to ensure that compatible advisories are displayed to the pilots.

Finally comes coordination with Air Traffic Control. Aircraft under the control of the conventional Air Traffic Control System operate in accordance with clearances issued by Air Traffic Controllers. In a mid-air encounter, collision avoidance equipments may issue resolution advisories that will cause controlled aircraft to violate their clearances. In order to ensure that the controller will be notified of the maneuver intentions of such aircraft, collision avoidance equipments will automatically transmit the resolution advisories they generate to the appropriate Air Traffic Control facility for display.

ATARS and BCAS can be distinguished based on the ways in which they perform the Collision Avoidance System functions that are summarized. Before describing ATARS and BCAS, a brief description of the Discrete Address Beacon System (DABS) is in order.

DABS

Two types of ground-based surveillance systems are currently used for Air Traffic Control. The first is primary radar which provides range/azimuth reports of aircraft positions

based on "skin paints". The second system is the secondary surveillance radar (or beacon) system that provides range, azimuth, identity, and altitude information. The existing beacon system employs ground-based interrogators and on aircraft Transponders that transmit pulse-amplitude-modulated messages to convey identity and altitude information. DABS is an evolutionary replacement for the existing Beacon System which retains the modes and functions of today's equipments while adding a "private-line" communications service whereby aircraft equipped with DABS Transponders can be uniquely addressed by DABS ground equipments. This Discrete Address feature of DABS ensures certain surveillance improvements and provides a Data Link capability that can support a number of services including Collision Avoidance.

ATARS

The Automatic Traffic Advisory and Resolution Service (ATARS) is a ground-based element of the separation assurance system that can reside within a DABS ground station. The principal surveillance task is assigned to the DABS equipments. The associated ATARS processor performs the threat detection and threat resolution functions. Coordination with Air Traffic Control is accomplished over the same channels used for transmitting DABS surveillance data to the Air Traffic Control facility. Traffic and resolution advisories generated by the ATARS ground processor are transmitted to aircraft in the conflict over the DABS ground-to-air Data Link. In order for an aircraft to receive and process such advisories, it must be equipped with a DABS Transponder and an ATARS display unit.

DABS ground stations will track all aircraft equipped with either today's Transponder or a DABS Transponder. As a result, an ATARS-equipped aircraft is protected from collision with any aircraft carrying either type of Transponder. In order for ATSRS to issue a resolution advisory, the aircraft in the encounter must be reporting altitude. An enhancement to ATARS whereby traffic advisories will be generated for aircraft without altitude-reporting Transponders is under development.

ACTIVE BCAS

The Beacon Collision Avoidance System (BCAS) is the aircraft-based element of the Separation Assurance System. A BCAS-equipped aircraft carries an interrogator-receiver for detecting Transponder-equipped aircraft in its vicinity and an associated computer that performs the tracking, threat detection, threat resolution, and air traffic control coordination functions. The coordination of resolution advisories with other BCAS aircraft and with ground ATARS is carried out through appropriate air-to-air and air-to-ground communications.

BCAS is being developed as two distinct system elements. Active BCAS is a relatively simple concept that detects Transponder-equipped aircraft by actively interrogating, and then tracking the resultant replies in range and altitude. It is restricted to generating climb/descend resolution advisories and to operation in low to medium density airspace by which we mean 6 to 10 aircraft within 10 NMI.

FULL BCAS

Full BCAS, on the other hand, can detect Transponder-equipped aircraft both through active interrogations and by passively listening to ground station interrogations and associated aircraft replies. Full BCAS will generate both climb/descend and turn right/left resolution advisories, and will be designed to operate in all airspace.

Both active and full BCAS can generate traffic advisories as well as resolution advisories.

ATARS/BCAS INTEGRATION

It is anticipated that DABS/ATARS ground stations will be deployed in dense terminal areas. Here collision risk, as assessed by the close proximity of large numbers of aircraft, is the greatest. In such airspace, ATARS provides collision protection to a large number of users at a low level of user cost because the separation assurance functions are performed on the ground and equipage requirements for aircraft equipped only for ATARS are minimal. In addition, in dense airspace, the threat detection function must be carefully tailored in range, aximuth, and altitude to local traffic patterns in order to control the number of unwanted alarms. It is relatively simple to so adapt the ground ATARS threat detection logic. A similar level of adaptation in BCAS units would require onboard storage of logic parameters indexed by map or navigational data.

Outside the airspace in which DABS/ATARS is deployed, collision protection will be provided by BCAS. While BCAS avionics are substantially more expensive than ATARS, the BCAS equipped aircraft carries its protection wherever it goes without reliance on ground equipments.

When a BCAS aircraft flies into ATARS coverage, onboard logic assures that BCAS-generated traffic and resolution advisories are properly coordinated. A pilot of an aircraft in conflict receives a fully compatible advisory whether his aircraft is equipped only for ATARS or for BCAS as well. The principal purpose for operating BCAS within ATARS coverage is to protect the BCAS aircraft from "pop-up" intruders which, early in the encounter, may be below the floor of DABS/ATARS surveillance coverage.

TRANSPONDER EQUIPAGE

It is clear from these brief descriptions of ATARS and BCAS that equipped aircraft are protected from collision with any aircraft carrying a Beacon Transponder. The equipped aircraft receives a resolution advisory only if the intruder is reporting his altitude through his Transponder. The protection provided the equipped aircraft is therefore directly equipped.

The domestic aircraft fleet consists of 2,500 Air Carrier aircraft, 20,000 Military aircraft and an active General Aviation fleet numbering over 200,000. All Air Carrier aircraft are equipped with altitude-reporting Transponders, and all Military aircraft with the exception of 3,200 or so light helicopters are similarly equipped. In the General Aviation category, over 65 percent are Transponder equipped and about 30 percent report altitude through their Transponders.

Federal Air Regulations assure that Air Carrier aircraft will be protected by ATARS and BCAS to a greater extent than one might suppose from these Transponder equipage statistics. In particular, all aircraft operating in Group I Terminal Control Areas and in enroute airspace above 12,500 feet must be equipped with altitude reporting Transponders. Currently there are nine Group I Terminal Control Areas which account for 30 percent of all domestic Air Carrier operations.

ASA LOGO

In conclusion, the development of an aircraft separation assurance system that is fully integrated and compatible with the conventional Air Traffic Control System is a challenging task. System requirements have been developed and a system architecture comprising conflict alert, conflict resolution, ATARS, and BCAS has been defined. These system elements make use of Air Traffic Control Transponders for detecting and tracking intruder aircraft. This design choice assures that aircraft which equip with ATARS and BCAS avionics will immediately receive protection from mid-air collisions. In addition, Air Carrier aircraft will receive substantial protection due to the fact that all aircraft are required to carry altitude reporting Transponders in much of the airspace where these carriers operate.

INITIAL DISCUSSION

OPENING PLENARY

Mr. Quinby - Thank you Clyde. I ask that the presenters and AT personnel accept some questions before we go to lunch. In asking the questions I will ask you to identify yourself as the questioner and address your question to one of the three presenters. And I will exercise the prerogative of the chair and lead-off with a question to Dr. Miller on the definition of "low to medium density" presented in his presentation as 6 to 10 aircraft within 10 nautical miles. I presume that's a radius, from own aircraft - does that have any altitude factor on it? Or is that a two-dimensional density?

Dr. Miller - 6 to 10 aircraft within ten nautical miles of own aircraft at any altitude.

Mr. Quinby - We don't have a good handle on definition of density for the algorithms that we're trying to play with here, witness the fact that that definition and the definition that the Tech Center BCAS evaluation activity in the Los Angeles Area uses for maximum is also a two dimensional density. I hope we can do better than that. Any other questions?

Mr. Mc Comas - I have a question for John Andrews. This may be answered in the Lincoln paper which I haven't had a chance to look at, but I think you made the statement that toward the end of your presentation that you would like the EFR system to accept pilot changes, logic changes, I guess I could understand that if these were changes of a planning nature or for example if he wanted to put intent in that he wanted to climb, but in the example you gave you suggested that the system comes up with a resolution and the pilot decides that it's bad. It seems to me that that immensely changes the depth of the problem, it introduces time now that's a variable and a potential for confusion among the participants, and I wondered how much thought Lincoln had given to that.

Mr. Andrews - The report covers that in very scanty detail and I don't think you'll find too many specifics in the report. The general concept is that the pilot complies with the safe but undesirable solution until the computer can replace it with a safe and desirable solution. In order to be most efficient the system should know ahead of time what the pilot intends to do but in some cases the input may arrive only after the initial decision has been made. For instance, if you know that a pilot is intending to descend to a certain altitude or wants to climb out to a certain altitude, that's quite simple to take into account in the computer decision-making process. As far as what specific form that input should take, it's probably different for different aircraft and different pilots and it may even depend upon whether the pilot wants to equip with an input device in his cockpit that enables him to interact. It may be a totally automated procedure in which the pilot informs the system of what his next waypoint is and says, "here's where I want to go and whatever you do don't interfere with my getting to this waypoint". The pilot doesn't enter it at all; it's something that the system simply reads and takes into account. I think that's something that perhaps should be discussed in the Work Shops tomorrow as to exactly what kind of pilot interactions (if any) might be desirable for different classes of users.

Mr. Quinby - I got a couple more off that same presentation. That neat DABS initial deployment coverage map I caught the 6,000 AGL altitude, but what dimension did you use for the radius of those circles?

Mr. Andrews - I don't think I could quote you the number although you could probably get it from the figure. It is based on a very simple assumption that coverage is limited only by the elevation cutoff which takes into account the curvature of the earth. It doesn't go out beyond the maximum range of DABS sensors until you get to a very high altitude (well above 12,000 ft). Those maps are quite optimistic for the mountanous Western Regions because mountainous terrain chops up the coverage quite a bit. But since the conclusion is that the coverage is bad in those states anyway, the simplified circular coverage does give an approximate picture of where you would have coverage.

Mr. Quinby - That doesn't then take into account the loss of angular resolution as you go on out towards the edge of coverage. It's not germain? And last does your decision-making by computer assume that you have any down link information such as turn rate or altitude change rate or does it assume that you do not have this information?

Mr. Andrews - No, it doesn't assume that additional information is provided and in fact we don't see that being a necessity to make this kind of separation assurance work. With a primary system, unlike a collision avoidance system, you're not waiting until the absolute last moment before you begin to intervene. If you do, you'd probably have a rather disruptive system. You want to exercise control in a way that enables you to be more gentle about the way in which aircraft are separated. And we don't envision anything being required for downlink other than the position and altitude of aircraft.

Mr. White - I would like to ask Mr. Andrews to what degree he looked at the question of non-accelerated flight. I believe the data shows that much of the flying that is done by aviation is done in stable conditions. I think that unless you look at maneuvering flight carefully you can make some bad assumptions and I wondered if they had made any determination about that. It wasn't one of the concluding questions, and I believe that it is one of the more important questions and should be listed.

Mr. Andrews - I'm trying to understand exactly what the question is. In the enroute airspace turns are very infrequent so that aircraft do fly non-accelerated a great proportion of the time which implies that a system that assumes non-accelerated flight is going to be right the vast majority of the time. The study that we did of how to effect resolution assumes that no matter what the acceleration profile of the aircraft is, the system has to guarantee that you will maintain safe separation. It may not have to have the same degree of efficiency in accelerated flight as it does in non-accelerated flight, but safety does have to be assured whether aircraft are accelerating or not accelerating. Is that getting at the point?

Mr. Quinby - I think John, that the degree to which your study considered accelerated flight situations on the part of both participants in a potential conflict was the basis of the question. Because granted that enroute is mostly unaccelerated you can't have a system that works only in the unaccelerated situation. So the question as I interpret it is what do you know about that system in accelerated flight conditions?

Mr. Andrews - If you'll look at the report you'll find out that in defining the logic detection criteria, we defined a two-part detection process; one part asking whether or not accelerations could result in an immediate conflict between aircraft, the other part asking if aircraft which continue on unaccelerated

flight paths will come into conflict in an extended time frame. The result is that for a situation in which unaccelerated flight can produce a conflict, you begin earlier to resolve and try to do it very efficiently. If it takes acceleration to generate a conflict you may begin later and you may do some things which aren't as efficient, like giving instructions to both aircraft rather than only one. It may require both aircraft to be given a new heading or a new altitude rather than only one. Accelerated flight may decrease lead time and result in a loss of efficiency but not a loss in safety and we believe that the system has no problems in that regard.

Mr. Quinby - Thank you John Andrews.

Dr. Koenke - John, I'd like to ask a question of clarification. You talked about pilot making decisions and you talked about the computer making decisions. When you talk about the computer making decisions are you specifically talking about a ground computer system or are you admitting to the possibility of an airborne computer system?

Mr. Andrews - The ground-based system is dictated more by the need for surveillance and coordination with Air Traffic Control than by whether EFR uses a computer or not, so it would be conceivable that you could do it in an airborne mode. BCAS for instance is a system which uses a computer in the air. It ties together two computers, one carried in each aircraft, to make sure they are coordinated. The fact that it's coordinated gives the flavor of one decision-maker being involved. You've got two computers in the air connected by radio link but in a schematic sense it gives the appearance of being one computer system with elements distributed between aircraft. So "computer" does not imply airborne or ground-borne. But it is true that if you put the computer on the ground you've got one large computer for every aircraft that decides to fly and you aren't asking each pilot to buy his own computer before he can use the service.

Dr. Jensen - For Mr. Andrews - Did you consider the problems that would arise procedurally and safety-wise in the case of failure of the system under EFR conditions IMC?

Mr. Andrews - We didn't go into any detail in analyzing failure modes primarily because you'd have to get down to a lot of detail before you can begin to do that. It's always possible as soon as you identify a failure mode to identify a way of providing some redundancy. We do believe that in such a system that pilots would have to be IFR-qualified in order to fly so that if the EFR service were unavailable the fall back position would be that the pilots would have to enter the IFR system in order to complete their flight. If you are familiar with the AERA program

there has been discussion of ways of providing a fail-safe capability there. Probably some of those same features would have to be provided in EFR. No matter how it's done, there are different failure modes and it's hard to compare systems. With the ground-based system if you fail, you fail for everybody in the airspace, which is bad. But at least you know when you fail and you can build a parallel system or you can use redundant coverage in case of the DABS network. (If you have overlapping coverage another sensor picks it up right away and you might not even know that one sensor went down). With airborne systems, if they're cooperative, you have the problem that the pilot may be flying around and not know that his system isn't functioning the way it should. He simply doesn't get warnings or doesn't get advisories on certain aircraft. He may fly for quite a period of time in IMC without being aware that there's some malfunction in the system. So the different failure modes are difficult to compare without getting into a lot of detail. I think a system could be described which could detect other aircraft even though they were "failed". So you could at least have one half of a system operating; that is, the failed aircraft could at least be seen by the other aircraft in the airspace. Such a system does have some advantages. But systems which you can't stay separated from other people and they can't stay separated from you when your electronics fail are difficult to evaluate. It does require being more specific about what failure modes you are concerned with and how they might be circumvented.

Mr. DeBaryshe - Mr. Andrews you speak of safety as one of your requirements, and comfortable safety. How does your organization define and quantify and measure the safety of these various systems in terms of the Air Traffic Control environment?

Mr. Andrews - I don't think we have a better measure of safety than anyone else does and of course it is something very difficult to quantify. In fact in the case of an EFR system, I'm talking about a new service, it's important that it not only be safe but that it also looks safe to potential users. Both are necessary. To introduce a new service or a new mode of flight may lead to safety requirements which are even greater than those required to preserve an existing mode of operation. How do you determine that a new system is safe given the potential for ill-defined failure modes? If the system is extremely safe the failures may be very rare events and it is quite difficult to come up with any quantitative measure of their likelihood. Frankly I don't know of any widely accepted way of demonstrating these extreme levels of safety. I think that perhaps the important thing is that the users who have to use the airspace look at the system and conclude that based upon what they know about it that it appears to have an acceptable level of safety, enough to allow its implementation. And the proof's in the pudding once the system is implemented.

Mr. Quinby - I'm afraid we have a very subjective, qualified and emotional phenomenon when we discuss safety. One wise speaker, I don't think it was Bill Flener, it could have been Frank White, said that safety in any transportation system is the ratio of intact arrivals per departure. Take that to lunch with you.

Mr. Quinby - I trust you enjoyed your lunch. We thank this morning's presenters, Dr. Clyde Miller, John Andrews, and Hal Becker. All three of those presentations plus anything that you want to ask Dr. Koenke or me is now up for questions. Questions of clarification, questions to assure that you understand what the presenters have presented. By asking questions or not asking questions you are not implying agreement or disagreement but we're given these opportunities to clarify any items that might have been touched too lightly for your perception by the presenters and the obvious conclusion on the part of the organizer is that everything is clear if there are no questions.

Mr. Graham - I would like to ask the Lincoln people and the Air Traffic people a question about the numbers or percentage of operations which are actually affected by this concept. If 90% of people can take off EFR and land EFR and not get involved in the Air Traffic Control System that seems to present great advantages. If 90% can take off from Podunk EFR but they wind up saying, well Kennedy Approach here I am, then the AT people have to deal with what I think they call a "pop-up". In that event I believe the workload associated is much greater, there are airborne delays I think which have to be contemplated, there's an increased safety risk about people going around in circles while they're being found a slot and the controller is diverted when he's doing that and that implies a greater risk to other flights. Now in round numbers what is the potential of the thing? How many people can actually take off and land under these rules, and how many are actually going to wind up involved with ATC anyway and would not those people be better off sitting on the ground instead of going around in a holding pattern finding themselves a place in the system?

Mr. Quinby - The question is a good one Walt, and while John Andrews is thinking it over, I'll remind you that he pretty much stayed in low density airspace and away from the issue of enroute terminal airspace transition and out of the heavily accelerated high density terminal airspace with his studies. Is that correct John? So from that standpoint it would appear that the most common EFR scenario is an EFR departure from a non-hub or an uncontrolled IFR airport and an R-NAV direct as possible route to another similar terminal for purposes of this study. That's what it sounded like to me. But I'll let him answer.

Mr. Andrews - That's right. One of the ground rules that we were constrained to observe was not to attempt to solve the terminal problem but to look at enroute low altitude airspace. Terminal airspace and transition are areas that we identified for further investigation. The way in which you enter terminal airspace probably depends upon where you are going because if you want to fly EFR to Kalamazoo it might be different than flying EFR to JFR or to a place where you have to reserve a landing slot. It may be that if you're going to certain areas the EFR system has to keep tabs of where you are and give your ETA to the terminal that you're going to. Whereas if you are going to other places it doesn't. And it probably depends on exactly how you do EFR as to which areas you can easily go into and which areas that you might anticipate a delay upon arrival. We don't have the percentage numbers; that probably requires more definition of what we mean by EFR in order to come up with any numbers that would be meaningful. And again maybe that's what one of the questions this Work Shop will address so that we can proceed to actually compute percentage participation and percentage savings that could be achieved.

Mr. Quinby - Keith can you add to that and also for my own amazement if you have any feel as to percent IFR versus VFR traffic in the system and percent IFR traffic in IMC. Those numbers if you've got 'em.

Mr. Potts - I don't have that information with me, but if we have the information we'll make it available to you. One thing I would like to say though is in what very little I know about electronic VFR up to this point in time, there is going to be some price of entry into the controlled terminal area regardless of whether it's high density or low density. If on arrival the aircraft that's operating under the electronic concept needs an IFR clearance to get into a terminal area there is going to have to be some advance information - it won't make any difference if it's a busy terminal or not - the factor of delay would be entirely different at each of those places but there would still be some required information. You know the solution to chaos is order so there's got to be some advance planning regardless.

Mr. Quinby - I think that it is safe to say that at this point in the conception of EFR and controlled terminal airspace we'll be operating in Instrument Meteorological Conditions under Instrument Flight Rules and the control of the Air Traffic Controller, regardless of whether we got there EFR, IFR or VFR. You can't access that airspace under the Federal Air Regulations without a clearance and those rules will survive at least until

there is a significant implementation of EFR and we know how to use it. A lot of this is going to have to be gained by experience. Further questions?

Mr. Busch - A two-part question I guess for John Andrews. One, he made a statement about flights unconstrained except during conflict - I'd like to have sort of a definition of what is the region of conflict, how does he define conflict? And, two he also made the statement that EFR must not prevent those desired aircraft from having a level of safety which is at least that of IFR today. The question essentially is what sort of metric if any is either quantitatively or subjectively used for making that sort of decision. I assume you arrived at some before you proceeded to the step you are today.

Mr. Quinby - Do you understand the questions, John? I have an add-on to the second question which I'll get to after you're through.

Mr. Andrews - If you are familiar with how Collision Avoidance Systems such as BCAS and ATARS have evolved in terms of defining conflicts, you are aware that they do it in terms of measures like time to closest approach, and distances between aircraft. We envision any kind of automated EFR as having similar criteria. The primary difference being that EFR is a primary system rather than a back-up system and it probably begins examining separations using an extended time horizon. BCAS doesn't declare an encounter to be a conflict until you're within 25-seconds to actual collision. A primary system such as EFR probably gets pushed back to something like at least 90-seconds in order to allow resolution time for achieving desired separation. So it is a mathematical criteria that defines a conflict and the definition is based upon projected proximity of aircraft.

The requirement that referred to preserving IFR safety is not a derived requirement in the sense that there is some other process that gives rise to it. It's essentially axiomatic in the sense that this is what we hear when we listen to Congressional testimony, when we look at FAA rule-making, and when we listen to the users. It's also a statement that's long been accepted within the FAA. It's not a statement that we attempted to prove - it's our interpretation of the net result of policy in Air Traffic Control in the last few years.

Mr. Quinby - Can I throw mine in John? I was just a bit disturbed by what I think you said - EFR to EFR separation may be less safe than EFR to IFR or IFR to IFR. Now did I understand you correctly?

Mr. Andrews - Yes, let me explain that. The EFR system does not necessarily have to be something that replaces IFR at the same level of safety that IFR has today with regard to the safety of the flight of an EFR aircraft. For example, (not that this is necessarily the way we do it, but for instance) suppose you decided that in order to allow efficient EFR flight you would like to allow a separation standard of substantially less than the three mile separation or five miles that is required in IFR today. You might require that EFR aircraft only stay one mile separated from other EFR aircraft. This might be justified because you have a very fast reacting system, well informed pilots, and hence that's a perfectly adequate separation. But when an EFR aircraft encounters an IFR aircraft you might have to stay three miles (not one mile) away from that IFR aircraft. How you do it may be actually dependent on the kind of users which are participating in the system. You could have a system that imposes differing levels of safety depending upon which users are involved in a conflict. It may turn out that you could define a viable EFR system that had safety somewhere in between the perceived safety level of the VFR system today and that of IFR.

Mr. Quinby - Are you simply offering a direct correlation between separation standards and safety of system?

Mr. Andrews - No, I don't think that they are directly related at all. In fact, safety is a function of a lot of things. How well coordinated is the conflict? What information do you have - (such as intent information) on the aircraft? A lot of other things impact safety. The important thing is that there has to be a way for a user who desired the highest level of safety to fly with at least as much safety as he has today. That may mean that he can't fly EFR. If he wants the ultimate level of safety he may have to remain IFR. Of course, if EFR could provide that level of safety, it would be all to the good. But the EFR system, in order to achieve the benefit of off-loading traffic from an IFR system, doesn't have to be acceptable to every aircraft that is flying IFR today. It only has to handle a significant number of aircraft: it only has to be acceptable to a large number of users. And a large fraction of the IFR traffic (and particularly the growth in IFR traffic) is going to be General Aviation aircraft which may be looking for a less complicated system and might accept a system which has fewer constraints and redundancies, a system that would be perceived to be somewhat less safe than IFR but would be perfectly acceptable to those users.

Mr. Quinby - That is compatible with the acceptability of the VFR system which is less safe by the record than the IFR system.

Mr. McComas - I'd like to go back to John's answer to the first part of this question. He brought up a very significant point that I think we should all take into account. He's talking about a primary separation system in which you begin tracking at a much earlier time. It seems to me that when we looked at the BCAS power budgets that it may not be in the wind to be able to do this. In a head-on at 600 knots - you could just about squeeze enough range out of a beacon link to make it work.

Mr. Quinby - I don't think that needs to bother him in his activity. But your point is well made for introduction at one of the Working Groups.

Mr. Stutz - Dr. Miller could you highlight again the differences between active and full BCAS including their saturation levels and where they would be used and maybe at the same time just comment, at least for my benefit again where they fit in with the proposed DABS system?

Dr. Miller - Let's see. Active BCAS - the active BCAS system is intended for low to medium density airspace - meaning by that six to ten aircraft within ten Nautical Miles and that roughly translates into Washington-Philadelphia that kind of airspace today. It is restricted to an up/down resolution capability. That is to say that it does not have available to it the precision bearing information that is required in order to get the bearing and velocity estimates that you need for horizontal resolution capability. It does have the capability to indicate intruder bearing for PWI Proximity Warning Indication or traffic advisory purposes. But again it doesn't have that information with sufficient precision to permit one to advise the pilot to turn right or to turn left to avoid a collision.

That is the active BCAS. It is highly developed; we think it could be installed and operational in the 1983 time frame if everybody moves out on it. It is relatively inexpensive we believe in the aircraft on the order of $27,000 off-the-shelf price for an Air Carrier version. For the General Aviation community we have a development on-going at Lincoln Laboratory and the target there is in the $5,000 area which clearly doesn't help the Cessna 172 fellow very much but would be appropriate for any number of business aircraft. So that's pretty much the story on active BCAS.

Full capability BCAS is designed to operate in all densities of airspace including very dense airspace and gets to the very dense airspace by virtue of using passive modes as well as active interrogation modes. The passive modes of BCAS are also susceptible to signal interference but they're susceptible to a different sor of signal interference than the active modes are so that you sort of have it both ways if you have a full capability BCAS on board. You can use active modes if they work, if they don't work you can use full passive modes, and if they don't work then you're in trouble. But the feeling is that a design can be developed in conjunction with some support from the ground that would operate under truly dense airspace and that means four times Los Angeles Basin today which is very dense airspace. That system is not as highly developed by any means as the active BCAS, it is targeted for the 1986-1987 time frame and I'll guess it will cost you something like $75,000.00 to put one of those in your airplane.

The feeling and the program at the moment for really dense airspace, recognizing that $75,000.00 is expensive by anybody's standards is that if you want to solve that collision avoidance problem in the really dense airspace the way to do it is on the ground. And a lot of folks don't altogether like that but if you want to talk about cost effectiveness it is very effectively solved on the ground through the use of ATARS. In that case the aircraft need only have on board a DABS Transponder which, incidentally, he needs for active BCAS, and an ATARS display unit which is not very different from his active BCAS display unit; it simply has a second dimension to it. If there is to be a traffic advisory display capability in an aircraft for an active BCAS application then that very same traffic advisory display capability can also be used to display the ATARS traffic advisory. The feeling is that a very effective high density solution for collision avoidance is the ground ATARS.

Now DABS is involved in all three systems, and when you say that you've got to say what DABS means. DABS to most folks means a DABS ground station deployment and in that sense DABS is not involved in active BCAS. Active BCAS uses the DABS channel, the DABS message design for air-to-air signalling and also in that we have an ATC coordination device on the ground which we called a Radar Beacon Transponder, so that the BCAS can tell ATC what it is doing. That device is not a DABS surveillance ground station; it is only a communications station which transmits on omni directional antennas and is a relatively simple device. The DABS signals are also used in active BCAS application to communicate from the BCAS aircraft to that ground Transponder facility for purposes of ATC coordination.

So it is accurate to say active BCAS uses DABS signals. It is not accurate to say that active BCAS requires first the deployment of large numbers of DABS surveillance ground stations as John Andrews showed in his EFR presentation where he's talking about the full up relatively expensive DABS surveillance ground station.

Full BCAS also uses DABS messages for air-to-air signalling and for air-to-ground signalling for ATC communications. It is not tied into a large scale implementation of DABS ground stations. It can operate, and is designed to operate, and one of the reasons why it is so blasted expensive is because it is designed to operate in or out of radar coverage and with DABS sensors or ATCRBS sensors or both together. It has to operate through brute force with ATCRBS ground stations and that means you've got to put a great deal of capability in the aircraft because you don't have the associated capability on the ground to help it out and the aircraft equipment becomes very expensive.

ATARS is not functional without a DABS ground station deployment. And as I pointed out in my briefing, the surveillance function, the threat detection function, and the threat resolution functions are performed by the DABS/ATARS sensor. No DABS sensor; no surveillance. No surveillance; no collision avoidance. The only thing that is additional in the ground ATARS is another computer, small by comparison, which is used for the threat detection, threat resolution, message formating and uplinking to the aircraft for collision avoidance.

Lt. Col. Feibleman - Back to John Andrews here for a second. John I think you made a comment that you didn't know whether or not an IFR aircraft needed to know about the EFR proximity. It that a true statement?

Mr. Andrews - In developing the talk I said that that was one of the questions that had to be answered. We concluded that at least the controller of an IFR aircraft needs to be informed about the presence of the EFR aircraft. If that controller does things the way things are done today he most certainly passes that information along to the IFR aircraft in the form of a traffic advisory at the very minimum. The more the IFR pilot knows about the traffic situation around him the better off he is. We're concerned, however, about imposing requirements for knowing too much because that may mean that you require a lot of avionics on board the airplane. But if the pilot or operator is willing to bear the expense we may be willing to provide him with as much data as we can and allow him to display as much as possible.

Lt. Col. Feiblemen - Okay, that clarifies it for me because I think that everyone knows even in the case of two IFR aircraft under the present system that if they don't know of each other that evasive actions have been taken even when the 1,000 ft. vertical or the prescribed lateral separation exists which could put the IFR aircraft into an unsafe position.

Mr. Quinby - And have done so historically. A little further on that John, an IFR aircraft outside of coverage being procedurally separated and an EFR aircraft in the proximity. That conflict out of coverage would pass unknown to the IFR aircraft. Is that correct?

Mr. Andrews - If you're outside coverage there is no way for the controller who is controlling the IFR aircraft to know that the EFR is there. The EFR aircraft may have taken off from a non-tower airport, for instance, and there is no surveillance. So yes, if you're trying to operate under those conditions you'll have trouble.

Mr. Quinby - So in that peculiar circumstance, Colonel your suspicion would be correct.

Mr. Drouilhet - To comment a little bit more on the answer to that question, if you are going to operate EFR outside of coverage where there are procedurally separated IFR aircraft the only way that that could happen safely is for the IFR aircraft to also be equipped with whatever it takes to do EFR. So they would be aware of the EFR aircraft if they were suitably equipped.

Mr. Quinby - By your conclusion then, coordinated avoidance would be necessary under those circumstances.

Mr. Drouilhet - That is correct.

Mr. Quinby - And autonomous avoidance not acceptable.

Mr. Drouilhet - Yes. The situation which you posed could not be allowed to happen.

Mr. Quinby - Under your tenets of your study.

Dr. Koenke - I'd just like to comment on this issue of procedural IFR and EFR co-existing, and in one way I agree with Paul and it's a question that arose during the course of the study. My conclusion was that probably EFR in that airspace meant the elimination of procedural IFR.

Mr. Quinby - That would be one solution; perhaps not very acceptable.

Dr. Koenke - Right.

Mr. Busch - John Andrews again please. I believe in an answer to a question from Frank White this morning concerning the question about accelerated flight you also talked about the question of level flight. If the intent of the EFR is to give maximum flexibility is it not expected that in fact you would be getting more types of step climbs and sort of parabolic flying to get maximum fuel advantage and thus the question of vertical changes is likely to be maybe even an order of magnitude higher than present vertical changes on enroute, and thus change some of the conclusions which you presented this morning?

Mr. Andrews - I don't think difficulties arise from altitude rates per se. Difficulties arise when you're trying to predict where the aircraft is going in the future. In other words, it's acceleration that's really the problem and not the rate itself. If you see that an aircraft is currently climbing and you assume that he wants to climb at least another 500 ft., then you might decide that instructing him to climb another 500 ft. to resolve a conflict is something that's very unlikely to inconvenience him. The problem would come about if you saw two aircraft 500 ft. apart in level flight and you would just assume that they were going to have 500 ft. altitude separation and then one aircraft suddenly began to climb. So I think the fact that aircraft are climbing or descending doesn't really cause problems; it's a question of accommodating changes in rates and you're right - the constant or cruise/climb conditions are something which hopefully EFR could accommodate with very little problem and hence not require an aircraft to step climb.

Capt. Berube - The question is for Mr. Andrews. It seems to me that in the original deliberations of Topic Group III the notion of flexibility associated itself with the concept of equivalent level of safety to, Visual Flight Rules safety if you will, in VMC. In the postulated assumptions two were arrived at which seem to me to need a definition. The first one was that aircraft currently operating VFR both see one another - well does everyone in this room that believes that all VFR oper-operating in VMC conditions can see each other all the time please raise their hand? Okay, that's point one. Number two, was the notion that under present VFR operations in VMC conditions VFR aircraft know what the other aircraft intends to do. How many believe that that's true?

Mr. Quinby - Sometimes.

Capt. Berube - Yeah, when you're in formation flight you mean or what?

Mr. Quinby - Well that's one example.

Capt. Berube - Okay there are some times. So we have two assumptions that have been arrived at which are not completely analogous to current VFR operations.

Mr. Andrews - I think that what you interpreted as being an assumption was merely an attempt to explain some of the types of Air Traffic Control that are carried out today and not an attempt to say that all VFR aircraft are always aware of each other. Obviously that isn't so. It is true, however, that aircraft are never vulnerable in the sense that the pilot of each aircraft has the potential for maintaining separation from other aircraft. Whether that capability always functions or not is questionable. We don't ask pilots to fly totally at the mercy of other traffic and I think that the question of whether or not that would be acceptable is a new question and certainly something different than what we do today.

Could we ask an aircraft to fly in the clouds depending upon other aircraft to avoid him while denying that aircraft any avoidance capability? Perhaps each pilot has too much confidence in his own capability, but at least today the pilot can look out the window when he's in VMC and look for other aircraft. And if he assumes that he's competent, he at least feels that his fate is in his own hands. If we violate that principle with EFR we are imposing something different and there is a question about whether a pilot would accept it. As for the question about autonomous resolution or coordinated resolution: VFR today is autonomous; pilots have to look and guess what the traffic is going to do. If they determine that the separation is inadequate they have to do something and watch their traffic. That's the way it functions. Our conclusion is not that that kind of a system can't separate the aircraft most of the time. It probably could. The conclusion was that it's a different problem when you're doing it electronically than when you're doing it visually. It's different because of the accuracy problems, the lag problems, the display problems, and the human factors problems. We had difficulty in finding any definitive answ rs to exactly how well you can do looking at a display and trying to maintain separation from traffic and how much workload it is. In fact there's been very little directly applicable research done. Perhaps some of the studies that have been done in Maritime Collision Avoidance are the closest analogy to that kind of a resolution process. In our judgment autonomous resolution has a number of problems that have to be worked through. Coordination makes things a lot

easier. If you have to put in all the electronics to do surveillance and determine the positions of other aircraft, then adding coordination doesn't seem to us to cost you a whole lot more. And if we found that it was really a problem, then it would be more important to decide exactly how good you could make autonomous resolution.

Mr. Quinby - Thank you John. I think we'll flag the questions for the moment unless you have a rebuttal to the rebuttal.

Capt. Berube - It really is not a rebuttal only to bring forth the point that the assumptions drive different conceptual designs and one of those you brought up a couple of times, Gil, is the notion that if you've had an autonomous system then you might very desparately want to have such things as turn and turn rate.

Mr. Quinby - We, however, cannot reject concepts because of the assumptions and hypotheses on which they're based without consideration and due judgment and that's what we're here for. I'll now turn the podium back to Dr. Koenke.

Dr. Koenke - This morning I said that one of the potential concepts which could emerge might be an add-on to or expansion of some of the existing ideas that we have and are working on for automating the IFR system. I also talked about the 9020 replacement computer program and mentioned that this might be a tremendous opportunity to get some input into that program to accommodate whatever concepts might come out of this Work Shop. So I've asked Dr. Zellweger to brief you on the 9020 replacement program as well as the automation work that we're doing which is called AERA.

9020 REPLACEMENT AND AUTOMATED ENROUTE ATC

Andres Zellweger

Federal Aviation Administration

Mr. Zellweger - I'm going to discuss two of the major activities which are going on in the FAA today in the enroute ATC arena. The first viewgraph shows you our overall advanced system, engineering program. Quent Taylor alluded to some of the things we're doing such as the road map we're putting together to layout the steps required to get this kind of ATC system.

If you look historically at what FAA's mission has been and how we've accomplished it, you'll see that we have tried to maintain and foster safe and efficient operation of aircraft in the IFR system. To get safe and efficient operation in the early days people equipped with radio equipment for communication and navigation. Radar was introduced to give controllers a more accurate picture of where the aircraft are in their jurisdiction. Some time later ground-based computers came into plan to provide flight and radar data processing as a planning aid for the controllers, the controller remained responsible for the planning and control of traffic.

More recently we have been putting in new systems and also developing additional ones that are starting to take over some of the planning and control of functions. Centers today have a conflict alert function, that lets the controller know if minimum separation standards are to be violated. We have enroute minimum safe altitude warning systems and enroute metering. We are developing a conflict resolution system that will give a controller possible alternatives for resolving a conflict situation. There's been a program to look at a flight plan probe that projects flight plans into the future to see whether or not the path ahead of the aircraft for a number of minutes is clear.

The point is, that all these systems, when they are introduced, leave us with an Air Traffic Control System that is quite labor intensive. It still is a procedural system.

It depends on sectors that reduce the number of aircraft controlled by one person in order to assist the controller in doing the planning and control functions himself. We see shelves and altitude restrictions in order to reduce the traffic complexity created by traffic going in different directions. Finally it is a system that depends greatly on the human, and we all know that people do make mistakes. It is a system that is prone to errors.

What then are we planning on doing? We see that traffic may go up. We see that fuel costs are probably going to go up and I don't really believe that the kinds of systems that I've talked about that are in the development process will give us a final solution to the problems I mentioned. For that reason we're pursuing a program we call AERA (Automated Enroute Air Traffic Control).

I view AERA as a logical progression of the systems that we are now developing or have recently introduced in the traffic control process. I think the difference is that we can envision an integration of these past systems; an integration to the extent where the machine makes use of the individual functions to do automatic planning and control and to generate routine clearances. We think that we are in a position now to give separation responsibility to the machine. I would like to mention the types of things that we feel the machine is capable of doing. It can recognize aircraft versus aircraft conflicts way into the future. It can recognize the ATC environment conflicts. It can get a feasible solution for conflicts taking into account a flow management objective. It can generate routine clearances using fuel efficient profiles. It can also perform progress monitoring independently of the planning and control functions to ensure the safety of the system. Finally, this type of a system can be well integrated with ATARS and the conflict alert functions.

An important point in looking towards an automated system is that we can get rid of procedural limitations because we can build a computer system that can look at many more variables and much larger regions of airspace. We can now project aircraft paths into the future far enough ahead, perhaps ten or fifteen minutes (much farther ahead than a controller could if he had to coordinate with controllers in other sectors) to give an airplane a clearance that he may desire, or to give him the kind of fuel efficient descent that he would like.

We are convinced that an automated system such as AERA can work within a global flow management system. It can communicate with terminals to negotiate acceptance rates. On the basis of these it can deliver aircraft at multiple fixes at differing altitudes. It could accept or negotiate flow management directives from a more central flow management facility. Given these constraints an automated system could do initial planning for each aircraft and later perform tactical execution of that plan.

The overall AERA system concept as we see it is a system where we still have a controller playing a very active role. The controller can intervene and evaluate the quality of service of the automated system at any point in the process. The controller can review the planned traffic flows, the metering, conflict resolution, the clearance generation. The controller is always there to talk with a pilot who has a special request. The normal clearances are generated automatically by the system and automatically transmitted to the pilot, via data link. Or, in the absence of data link, possibly by a voice response system where voice signals are generated and transmitted automatically over voice channels.

AERA is a system that can effectively use a lot more information about aircraft than today's three dimensional flight plans. I said earlier that the highly automated system can deal with many more variables. AERA can accommodate altitude and speed profiles for specific aircraft in specific situations. With this knowledge, it is possible to minimize fuel burn and provide flight path flexibility to the pilot.

An important aspect of the AERA concept is its ability to handle system failures. If we are going to depend on a highly automated Air Traffic Control System that generates clearances for airplanes we have to be sure that the system cannot have failures that compromise safety. I don't have the time today to go into extensive discussions of how we view the failures to be handled in the AERA concept but I do want to point out that we feel that we have a concept for automation in which neither the controller nor the pilot are ever put in a situation beyond their capability even in a case of a massive failure.

The AERA control process should be applicable to the enroute and to portions of terminal airspace, both in mixed and Positive Control Areas. It doesn't require special avionics. Of course if one expects to get all of the benefits of direct fuel efficient flight, that a system like AERA can provide, equipage helps. If you have a DABS Transponder, if you have an R-NAV system, if you have a flight management system you're likely to get much better service from the AERA computer.

To build an AERA system, and I think we're still a long way from having a highly automated Air Traffic Control System that can be implemented, we're going to need an extensive effort in system design and in software design. There are some major issues that still need to be addressed. Over the past year, we've made tremendous progress in coming up with an overall system concept for AERA. A concept report was written by a group of industry and FAA people and will be published sometime this Winter. We still need considerable work in the whole area of defining the man/machine interface for an automated system. The concept document hints at how a human controller would work with the system but more work is needed. We need to look at some of the details of achieving the fualt tolerance in the computer system so that we can be sure that no faulty clearance ever gets sent to a pilot. We have taken a look at the computer systems Bell Labs has built. Something like 50% of the software in that system is devoted to making the system error free; to making sure that errors do not propagate into the data and the like. We have to do the same type of thing for the Automated Enroute Air Traffic Control System.

Finally I don't think we're going to implement AERA overnight. It has to be a gradual transition. It is not yet clear what the steps in this transition ought to be, but we do know that each step must provide considerable benefits. Finally to implement an AERA system we need new Air Traffic Control Computers. The current computers do not have the capacity nor the kind of reliability that will be needed for Automated Enroute Air Traffic Control.

Next, I'm going to talk about the computer system we expect to build, not only to accommodate AERA but to accommodate Air Traffic Control evolution from 1990 to the year 2010 or beyond. We have started planning for a new computer system that we feel is needed to handle increases in demand and anticapated ATC evolution. Today the human plays the largest role in ATC,

but as traffic increases and the demand for services increase we see either increases in personnel or the computer taking on a much larger role. The intent of the computer replacement program is to provide a system that can evolve as time goes on at an acceptable cost.

The program that the FAA has undertaken is based on several very important assumptions. The first assumption is that we're going to try to develop a computer system that can also perform Terminal Air Traffic Control. The system we're going to procure will go into the twenty-three centers, the current twenty enroute Air Traffic Control Centers and three offshore centers that we have. When we go out to procure this new computer system we will ask industry to design a computer complex for the long term; complex that could accommodate AERA. Our specification that will go to industry will have in it requirements for AERA, and the designs industry comes back with will have to accommodate AERA. The initial system that we will build and buy will be for Air Traffic Control as it will exist in, say, 1988 to 1990, which is the time in which we put the new computers in. The initial system will not have hardware and software for AERA.

That gets to perhaps the most difficult problem in getting this new computer system into the field, the transition constraints. When a new computer goes in it can have no adverse impact on Air Traffic Control. I don't think any of you would like it if suddenly one day we said, "well, we're not going to be able to provide you with Air Traffic Control at the Center for the next two days because a new computer is being installed". And then after it's put in if we have to say, "well, I'm sorry but for the next two hours the system isn't going to work because we've found some problems on this new system we've installed". The new system is going to have to go in, the old system is going to have to be there for a period of time, and we'll have to be able to switch from the new system to the old system very rapidly. That means that the controllers will have to do Air Traffic Control pretty much the same with the old and the new system at the time of transition because it wouldn't do to have a person control air traffic in a new way with a new kind of display, new pictures, a different format for message entry and output and then have to switch to the old one because suddenly the new computer has crashed. A lot of training is going to have to take place, and our goal is not to have to increase staffing during this transition period. I'm putting this viewgraph up for you because I think it shows a very important point.

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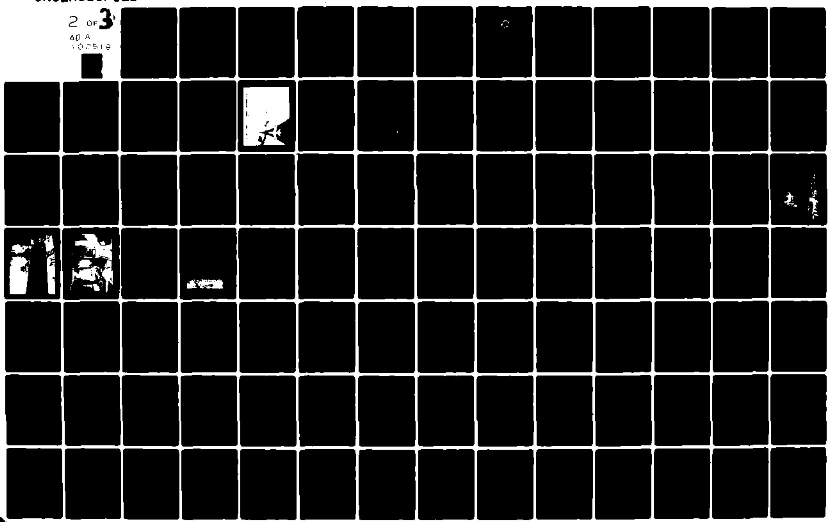


I've talked about trying to accommodate existing Air Traffic Control procedures from the controllers' viewpoint. Putting in a new Air Traffic Enroute Air Traffic Control Computer System also requires interfaces with numerous other systems that FAA owns and operates; the variety of radars that one might have to accept, the communications with other centers, with terminal areas and Flight Service Stations. All of this will have to be accommodated by the new system, at the time at which the new computer goes in. Our assumption for planning for the replacement of computers is that we're not going to tie ourselves to any plans in other system developments. For example, we're not going to make the assumption that at the time a new computer goes in,a new communications system will be available. We're going to track the other programs that are upgrading other facilities that this new computer will have to work with and make sure that at the time the computer goes in it works with whatever is there.

This viewgraph is a recap of some of the things that I mentioned earlier but it does show a function evolution of Air Traffic Control. I think that in coming up with the design of a new computer system it's very important that we take this evolution into account. For example, if you go out and build a flight data processing sub-system as it exists today we'd being doing ourselves a disservice. We already know from some of our studies that flight data processing is going to have to be done somewhat differently to accommodate AERA. We want to make sure that when we design the sub-systems that will initially go into the new computer so that they are geared for the evolution that we foresee. For that reason it's important for us now to know as much as possible about the kind of evolution that one might see in Air Traffic Control.

I want to re-emphasize the point that Ed made this morning - it's very important for those of us who are doing the planning for new enroute computer systems to know what you feel might happen to Enroute Air Traffic Control in the future. We need to know the functions the new enroute computers will have to support to make the specification for the computer as complete and informative as possible. Sure we're going to have flexibility in computer but it's not enough just to specify that you want a flexible computer. The more you can say about the likely direction of ATC, the better off you're going to be with the designs industry comes up with.

We not only have to accommodate new functions in Air Traffic Control but as I mentioned earlier, we're going to when we put the new computers in, live with the system that exists at the time. Interfaces will change with time. We want to make very sure that when we get the new computer system it is designed to accommodate evolution in the surveillance systems. I don't know if we'll get, for example, a satellite surveillance system during the life span of this new computer but certainly we will go into a much more extensive DABS system perhaps even a DABS network. The design of the new computer system must take these kinds of evolution into account.

A number of characteristics are very important in looking towards our new computers. I've talked a little bit about having to fit into the existing ATC environment. We also want to fit into the existing physical environment. We would like not to have to go into an extensive rebuilding program in our enroute centers. We've done some studies and we think that the room is there or will be there with possibly minor modifications to some of the centers to both put new computers in and keep the old 9020 systems there until we have the confidence needed to put the switch and permanently put the new system on line.

The system is going to have much higher levels of availability than today's system has, even for doing the kind of traffic control we do now. As we add near term functions like conflict resolution, possibly flight plan probes, the controller is going to become more dependent on the computer. I don't think we can tolerate a computer system that is not available all of the time. We don't want a system that has a vastly degraded mode of operation over extended periods. We would like to get away from the kind of back-up that we have today. The broadband system or even the DARC system that does some radar data processing. We would like to build a new computer to have available to the controller a-l functions at all times. As we get into higher levels of automation, i.e., AERA, reliability and availability become even more important because I can't really conceive of back-up modes under normal operating conditions for highly automated aircraft control systems.

Maintainability is another very important aspect. Over the past few years FAA has been stressing the importance of building new systems that can be maintained at reasonable costs over their entire life cycle. When we design and build a new computer system we're going to pay very close attention to how easily it can be maintained.

Another aspect that's going to be important is the ability to grow technologically. We don't want to be in a position with our new computers to have to change the whole system out at one time. We would like to get a design for a computer that's evolutionary; a design in which you could replace individual modules as they might become outdated or as the function that's being performed by that module no longer fits into the module.

There are four functional areas that we've chosen to use in putting together a description of functional requirements of a new computer system. The particular choice of functional areas was very deliberate. They break the system down into such a way that one could isolate different interfaces in different places. For example, the external input-output function is that functional area that deals with the communications system with the outside world. We would like to have any change in the communications system handled at that level. Similarly there is a lot of basic processing of Air Traffic Control Data, the kind of flight and radar data processing done today, that one would like to isolate. The functions for planning control also are a separable piece that should be designed to be independent of the functions that perform the basic ATC data processing. At the other end of the picture we see the interface with the controller. We would like that isolated from the other parts of the system so that as we evolve towards higher levels of automation, as the console that the controller works with changes and the programs that support that change, we could isolate the necessary changes to a specific area of our new computer system.

Finally, I would like to say a couple of things about how we are going about acquiring the new Air Traffic Control computer. The enroute ATC computer system has been designated as a major system acquisition. That means that we have to abide by the Office of Management and Budget Circular A-109. A-109 is based on an acquisition philosophy put together by the OMB to foster competition in industry to get the best of industry ideas and concepts into government procured systems. The intent of A-109 is to have as much competition as possible among various components of industry in building a new system. We at FAA have thought a great deal about how to use A-109 most effectively in the acquisition of our new computer system and we feel we've done a pretty good job in tailoring A-109 to the acquisition of the new computer. We expect, sometime around the end of this calendar year to have a specification ready for the new systems.

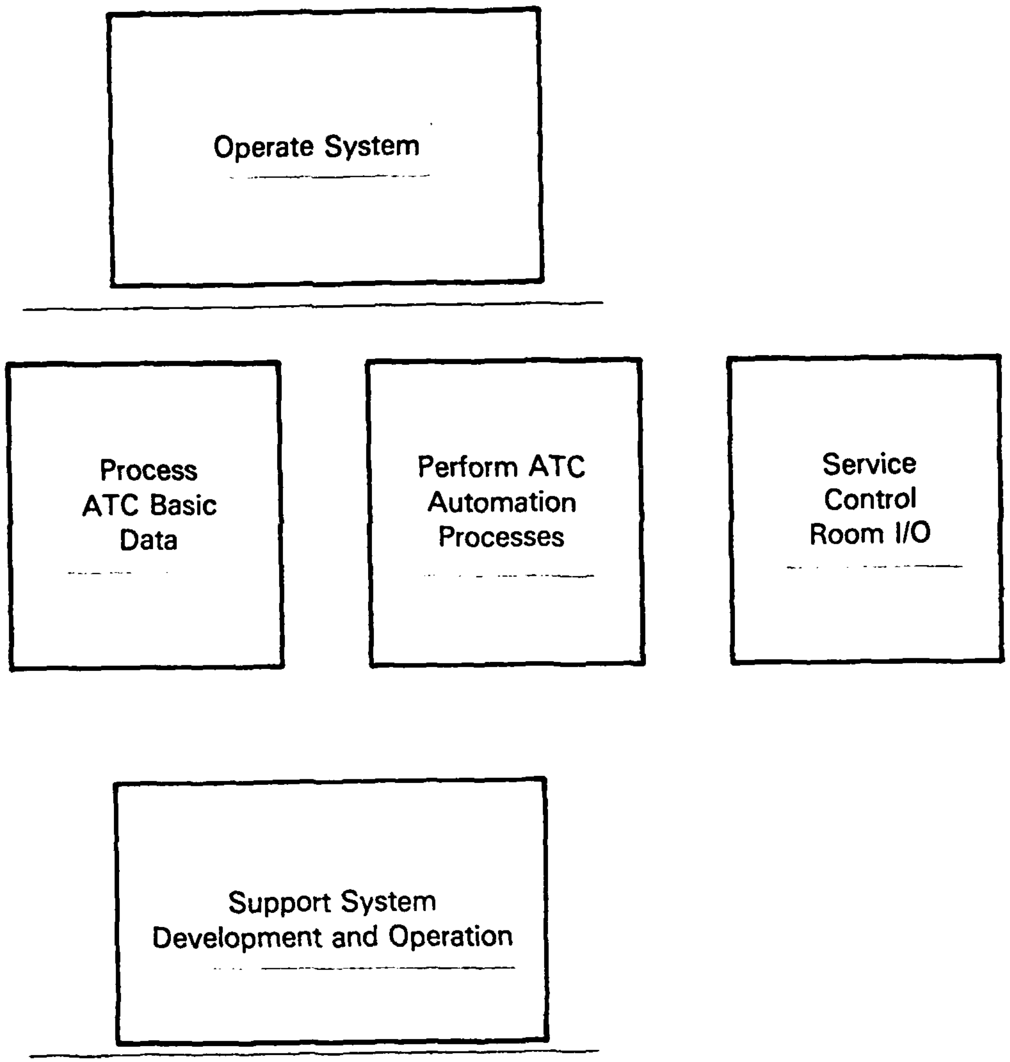
Sometime in 1982, we will award perhaps five contracts to industry for parallel development of concepts for a total new ATC system. Concept development would go on for approximately nine months. All the contractors will keep on working after that as we evaluate the concept phase outputs. When the evaluation is completed (after a few months) we will eliminate some of the contractors and proceed with a smaller number, probably two to three.

The contractors left at this time would be ones that have the demonstrated capability to do the entire job - the full design of the system; the construction of a prototype; and the implementation of the system. The design contractors would then go thru a detailed design of their new Air Traffic Control Computer System. As they get deeper into the design they would begin to concentrate more on the initial system to be installed, but in the early part of the design they would consider a total ATC System including the AERA system that we've talked about. During the design phase the contractors will build a critical sub-system for us, that we will use to convince ourselves that their approach works and to validate the analytic models they have built for us of their total system design.

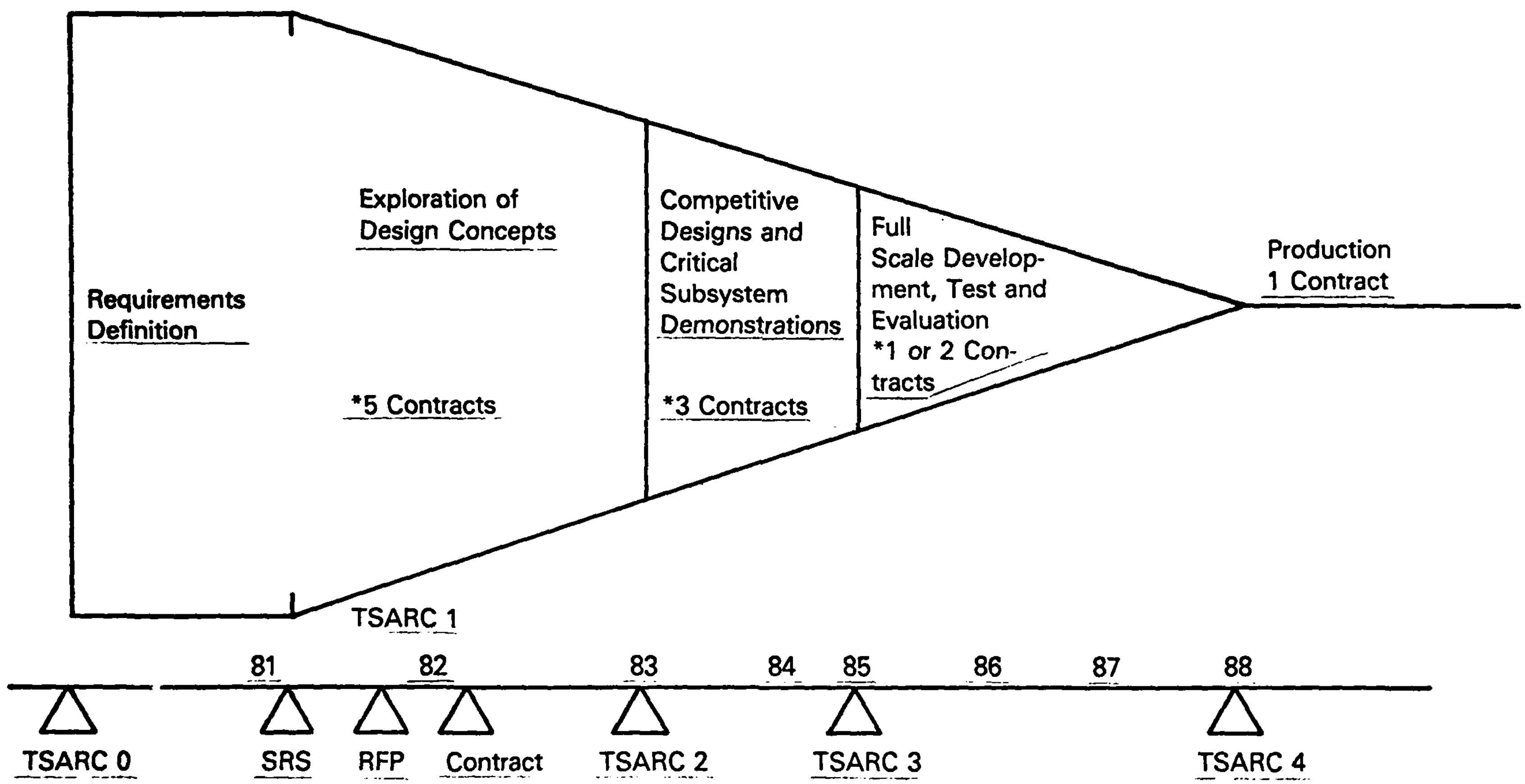
Finally, we would go into the prototype, the first article phase, with one or two contractors. The decision there is obviously going to depend on whether or not there is a great diversity and risk between two; whether there is a great difference in the type of systems people are still working at this point in time.

Finally, we expect that somewhere around 1988 the first system would be ready for installation in the field. Thank you.

Functional Areas



FAA Implementation of A - 109



*Nominal Number of Contractors
Actual to be Determined

ARTCCs and Radars

FEDERAL AVIATION ADMINISTRATION

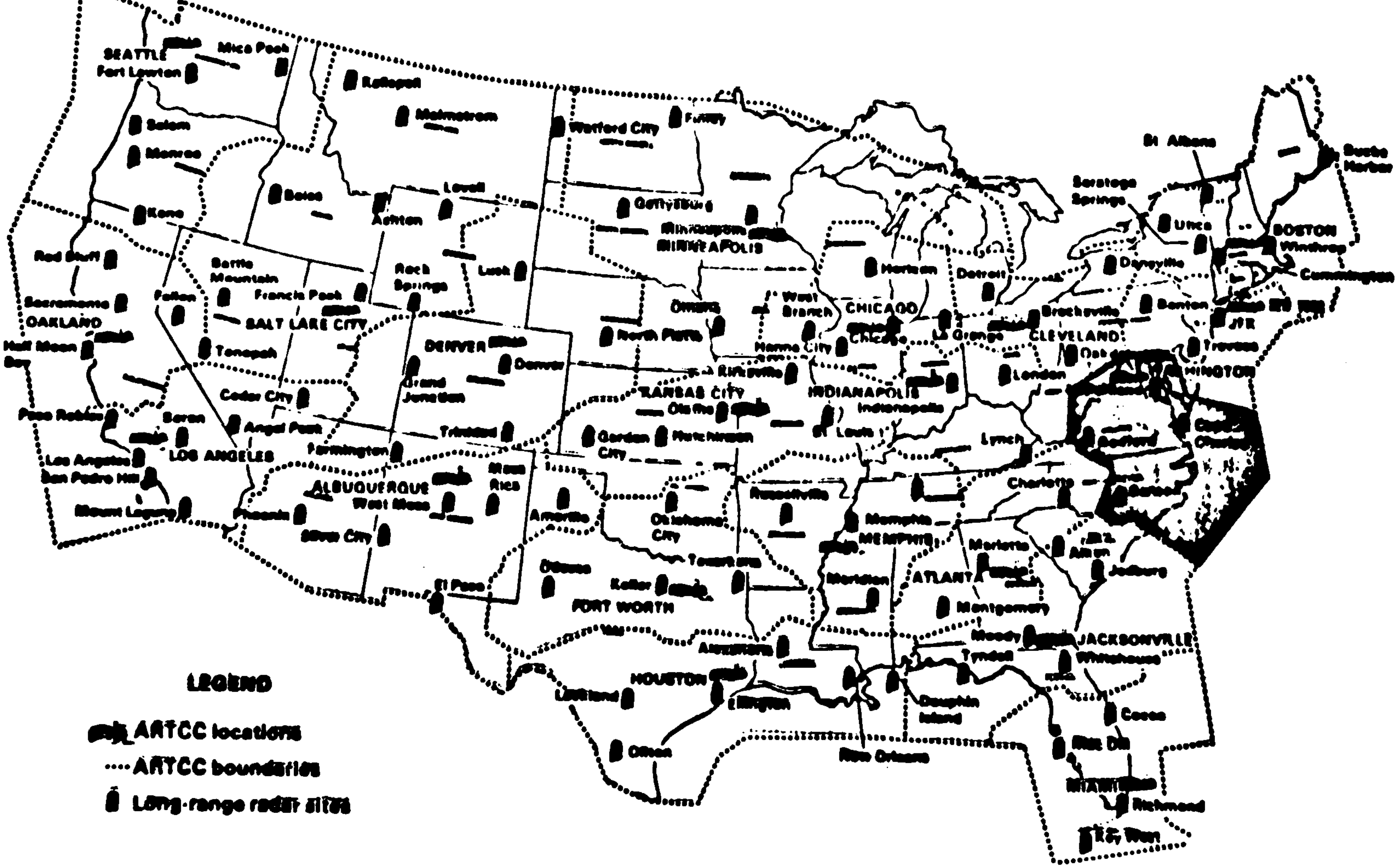
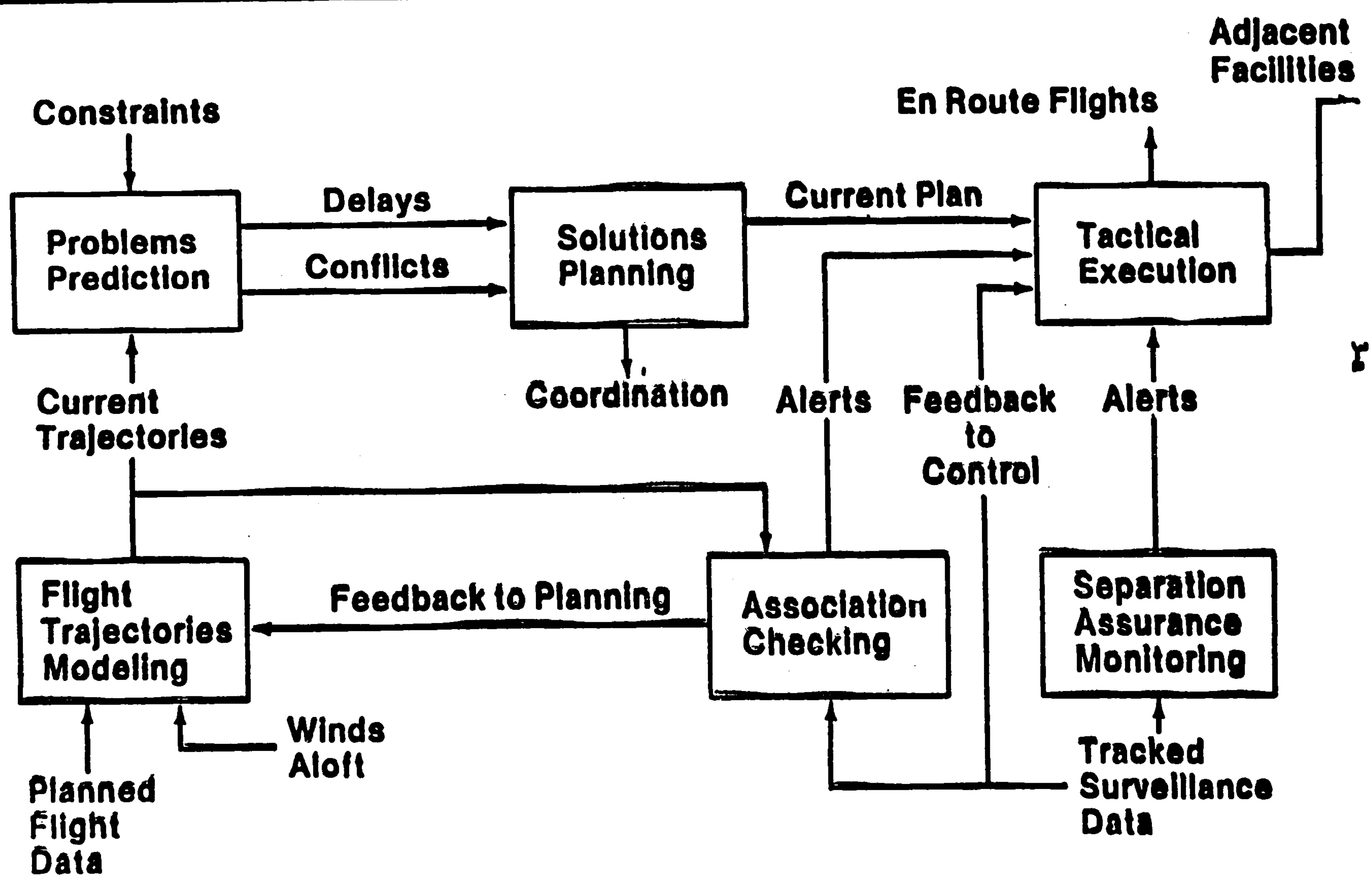


FIGURE 1-1

Major AERA Functions



COCKPIT DISPLAY OF TRAFFIC INFORMATION

Harry A. Verstynen, Jr.

Federal Aviation Administration

I'd like to start off by trying to give you some idea of what a cockpit display is at least in our own minds. It does go under several other names and many years of research was done at MIT - back then it was called ATSD or Airborne Traffic Situation Display - but basically the concept is the same. And I'd like to stress the word concept in that CDTI as it exists now is not a piece of hardware and it's not a particular implementation concept. It's really a concept for displaying traffic information to the pilot and a concept for how he uses it. Assuming that the concept works out where the advantages outweigh the disadvantages, and is implemented in some form, there are any number of possible data sources that could be used, some ground derived and some air derived.

There are also many possible ways in which the information could be displayed to the pilot in the aircraft; weather radars, dedicated displays, combined with map displays and flight management displays, EHSI's and all kinds of things; and we are trying to look at possible combinations. In the research program which I'll be telling you about we're trying to deal with the multiple possibilities of how the CDTI concept might be implemented someday by treating the hardware implications that would be involved in CDTI as parameters in the research. For example we're treating sensor noise as a parameter, we're treating lags as a parameter, and we're treating update rates as a parameter.

So with that in mind I'd like to show you some lists. The first list is some potential passive CDTI applications. What I'd like to stress here is that what I'm showing you are functions which have been postulated for CDTI over the years and we do not know how many of these postulated functions are practical and workable in the real world and how many of them are really just dreams, or nightmares depending upon where you stand. As you can see, CDTI is kind of the embodiment of the story of the pilot who's flying along and, unfortunately, the engines quit. Fortunately he has a parachute. Unfortunately his parachute doesn't open when he jumps out. Fortunately there's a haystack below him. Unfortunately there's a pitchfork in the haystack. Fortunately he misses the pitchfork. Unfortunately he misses the haystack.

CDTI is in fact a classic good news/bad news joke - with each one of these functions there are lots of potential advantages and there are some potential disadvantages. What we're really trying to do in the CDTI program is ferret out which of the advantages are real and which of the disadvantages are real.

The first thing a pilot would have is a passive function. (Passive is defined as the use of the CDTI in which there is no Air Traffic Control clearance required). The pilot is really in a monitoring role. If he sees something on the display he doesn't like he can ask for an explanation from ATC and, of course, the pilot retains his traditional emergency authority in which case he can take whatever action is necessary and explain it later.

But the point is that in classifying these we divide them along those lines and we're trying to pursue the passive function first in our research because we feel these are the ones that would become certification issues first and then treat the more active functions later in the research program. Some of the ones that we've identified as passive functions are situational awareness, and I'm not going to go thru all the potential advantages and disadvantages because many of them are intuitively obvious. Blunder detection and recovery, reduction of separations, hardware failure detection and recovery, and that's both on the airplane and in the ATC system, and the monitoring of automation. This is one of the key interests that the FAA has in the CDTI concept and that is that it may actually be the price of admission for putting highly automated systems on the ground. In other words, the pilot may not be willing to accept an automated clearance without some independent way of checking his position relative to other airplanes.

As we go down the list of active functions we can see that they include spacing and merging in terminal areas, flying of typical kinds of VMC patterns in IMC conditions, conditional clearances, primary separation, airport surface operations, and collision avoidance. And I'd like to stress two of them here - collision avoidance and primary separation. We do draw very strict lines between these functions in the FAA, in our thinking about how these functions are performed in the system. In the concept of Electronic Flight Rules the function that we're talking about is primary separation, and we do believe that CDTI may have some applications in that area, but the program does not address cockpit traffic displays for primary separation in low density airspace until much later in the program. If that's wrong, this would certainly be a good forum to get feedback on whether we have our priorities right.

So, in spite of the fact there are all these potential functions that CDTI has, and in spite of the fact that this concept was first postulated in 1946, and there have been many, many years of research dealing with various issues associated with CDTI, we have not yet reached critical mass. We do not have the data that is needed to make operational implementation decisions about CDTI. The research over the years past has tended to stress the advantages of CDTI and the potential utility that is might have under various circumstances, and that's natural for research. However, we've now reached the stage where in order to consider it as a potentially viable operational concept it must be treated in an operationally realistic environment and all of the potential liabilities that this kind of a concept may have need to be full explored in addition to the potential advantages that it may have.

That's really where we're coming from with the CDTI research effort that we have underway now. To get answers to these questions that still remain, in 1977 we started a joint program with NASA. We spent about a year in a joint planning exercise and we are now well into the execution of the program. The program that we have identified involves the FAA Technical Center, NASA-Ames and NASA-Langley, in addition to a number of different contractors who are involved thru those three government centers. The first phase of the program really concentrates on the parametric studies that I've been talking about where we're trying to deal with such issues as what size should the display be, how much resolution do you have to have on the display, what are the implications of it being located in the pilot's primary scan, versus being out of his primary scan? What are the maximum levels of sensor noise that you can tolerate before you get significant degradation to the performance? What are the effects of lag? How well can the pilot judge his position relative to another airplane?

In this Phase I effort we're really doing a parametric study with the facilities that we just happen to have available to us. In parallel with that, we are building into a full system simulation capability where we will be connecting full workload cockpits at the various centers with the ATC simulation capability that exists here at the Technical Center, so that we can run closed loop, real-time, dynamic simulations with both pilot and controller in the loop to try to look at the CDTI concept in as realistic an environment as we can create in simulation. And then, of course, we have some plans for flight tests further down the road.

I'd like to show what the objectives of Phase I of this program are. We want to determine the ability of the pilot to detect errors under realistic workload conditions, we want to

determine what the impact of CDTI is on his other traditional piloting duties, we want to determine whether a pilot, having received traffic information, would take unjustified unilateral action to a perceived conflict, to determine the ability of the pilot to recover from a separation loss in both single and multiple aircraft situations. These issues have a significant impact on his willingness to accept automated clearances, in spite of the fact that Dr. Zellweger just said that in the future the computer is not going to give any bad clearances. We want to look at the ability of the pilot to provide back-up separation in the event of various ATC failure modes, to determine the contribution of the pilot in detecting airborne system failures and ground based system failures, to determine the ability of the controller to space non-CDTI equipped airplanes in a mixed environment, and the ability of the controller to detect and correct an error by a CDTI airplane. These are not all of the issues, but they are representative of the kinds of questions that we feel like we need reasonable answers to before decisions can be made to implement or not implement the CDTI concept.

In the capacity area there's a whole host of similar questions and I really ought not to go through them because I would like to get to the point where I'm going to tell you what we've actually learned in the program so far. But you can see that there are objectives in the program that have to do with the potential impact of CDTI on the capacity of the system and on the efficiency of the system.

First, the work that we have completed so far at NASA Langley on the traffic display concept - the CDTI has been implemented on the EHSI in the TCV-737 airplane and flown in a non-interactive mode where canned traffic was provided in the onboard computers in the airplane. The pilot had to fly his own aircraft in an arrival sequence to a typical terminal area using a complex arrival path. Certain blunders were introduced and the pilot's ability to detect that blunder ahead of time and the particular recovery that the pilot chose to use was noted in these studies. Also some simulation studies have been run to compare various kinds of cues that can be given to the pilot to use to provide certain separation in terms of either time or distance.

A parametric study was run to look at the effects of display size by taking a certain display and then masking it down to smaller sizes and running it over a series of runs with different pilots.

At NASA-Ames a symbology study has been conducted where groups of Air Carrier and General Aviation pilots were brought in from the San Francisco area and presented with slides which

showed various kinds of symbology options for CDTI. The pilots' preferences for these symbologies were noted. The symbology preferences of these pilots were then programmed into the TCV preliminary flight test effort mentioned previously. Also at Ames, other information for the pilots, such as own ship altitude, other ship altitude, flight path, flight path predictors, and airport symbols were coded using this preferred symbology and compared with more conventional concepts, such as data tags in which a pilot got that information alphanumerically. Also Ames took the static symbology studies I just mentioned and ran those on into some dynamic symbology studies that turned out to be perhaps the most enlightening studies that we've had so far, and I'll mention those further in just a moment. These dynamic studies were done for both horizontal and vertical situations.

In work that's currently underway, here at the Technical Center we have the first CDTI study to get a preliminary idea of the potential impact of CDTI on the controller and on the ATC system. (I say that that's underway, actually the first field controllers come in to start the data collection on February 19, but believe me we've spent almost a year now in planning for this and from our point of view it's well underway). We also have a highly modified GAT II simulator here at the Center which will be used to look at the potential impact of CDTI in a low-cost General Aviation implementation, using a conventional Bendix weather radar implementation of CDTI. The baseline studies for that work have already started. We are planning a series of intermediate flight tests using the ATARS display and the ATARS hardware. We are also planning a dedicated set of flight tests using a T-39 aircraft (or Sabreliner aircraft) with a very high quality color CDTI right in the pilot's primary scan location. Those tests will be done in a year or two at Philadelphia.

At Langley there is currently underway in a DC-8 simulator a sensor noise study to look at the impact of a range of sensor noises - potential error in the sensor. There's a ground speed resolution study to determine how accurately you need to know ground speed on the other airplane and what effect that has on your ability to space yourself on that airplane. We're also preparing for some L-1011 flight tests in which a passive BCAS type of sensor will be used to feed a CRT display so that we can run some very preliminary flight tests, just to get our feet wet on the problems involved in flight testing a CDTI.

We have a CDTI procedures study under way, under contract with SCI. We have a flow stability analysis under way under contract to Analytical Mechanics Associates. Also at Langley, the Sabreliner flight tests are jointly being planned with the Technical Center.

At Ames there is an electronic VFR study underway. The shakedown of the simulator for those studies has been completed and the first subject pilots will be brought in in about another two months. In these studies a pilot will be flying a round robin flight and will be exposed to certain intruder airplanes with certain kinds of fixed geometries and altitude separations and so forth and he'll be given a number of different display options and allowed to maneuver relative to that other airplane. The objective is to find out how well he can detect whether this intruder airplane is in fact a conflict or not and how well he can maneuver to minimize the conflict before he would get into a situation that would involve the triggering of some sort of an automated CAS (BCAS or ATARS).

Following the Electronic VFR Study, plans are being made for a CAS-CDTI interaction study so that we can look at some of the issues involved in what happens when the pilot has a traffic display and a CAS display in the cockpit at the same time. There are potential ways in which those two may reinforce each other and there are ways in which one may in fact destroy the utility of the other.

I'd like to briefly review what I perceive as some of the things that we've learned from the CDTI program so far. One of the things that we think we've learned is that a CDTI is not a CAS,; that is to say that a pilot is a poor judge of his situation relative to another airplane when that information is presented to him at the last minute. We ran some experiments at NASA-Ames where a pilot was presented with a CDTI-like display and the intruder airplane was presented to him approximately 60-seconds before the point of closest approach between the two airplanes. He was given four 4-second updates on the position of that airplane and so at 44-seconds before the point of closest approach the display was turned off and the pilot was asked to make a binary decision: was the other airplane going to pass in front of behind. There were a whole series of variables in this experiment. Some airplanes passed ahead and some behind and some came from the right and some from the left. All were co-altitude. Some were 3,000 ft. miss distance, some 6,000 some 9,000. Anyway, from those studies we found out that with no aiding or with very simple kinds of aiding such as just a vector that showed the heading of the other airplane, and in maneuvering situations where either own ship or the other airplane was turning,

the error could range as high as 50%. In other words, the pilot could make just about as good a decision on whether the other airplane was going to pass in front of him or behind him by flipping a coin as he could by looking at the display. Now as more and more aiding was provided to the pilot, such as flight path predictors that were based on bank angle and airspeed, turn rate predictors and that kind of thing, the errors were reduced. But they were not reduced to zero, they were reduced down to the 10, 15 or 19 percent range. So that's still a very high error rate when you are talking about a function that's as critical as collision avoidance. And I'd also like to point out that that experiment was very esoteric in that the pilot had no other workload to perform (he didn't have to fly an airplane while he was making these judgments). He just sat in front of a display and stared at it. Also the data was perfect; there were no lags, there was no noise, or any of that kind of thing.

So, even though the intent of that work was not to prove or disprove CDTI as a CAS, we feel the data is very applicable to that situation, and as of this moment we feel it's safe to say that CDTI is not a CAS.

Now that does not mean that CDTI does not have a primary separation function. With these experiments and from experiments that we ran later, we found out that if you give the pilot more time (in that case we gave him 16-seconds) to make up his mind whether the airplane is going to go in front of him or in back of him, that is if you extend that out to like 52-seconds, you find out that the error rate goes down significantly. We also found in other experiments that if you show that traffic data several minutes before the conflict occurred, not just 60-seconds as you would in a CAS implementation, the pilot in fact can detect a conflict well before it develops to the CAS stage and he can avoid that conflict by making very gentle maneuvers that probably would not even be felt by a passenger in the back. And we also found that these don't have to be straight line simple encounters for the pilot to detect them. In the Terminal Configured Vehicle experiments the pilot was detecting conflicts on very complex three dimensional paths in the terminal area where his workload was relatively high.

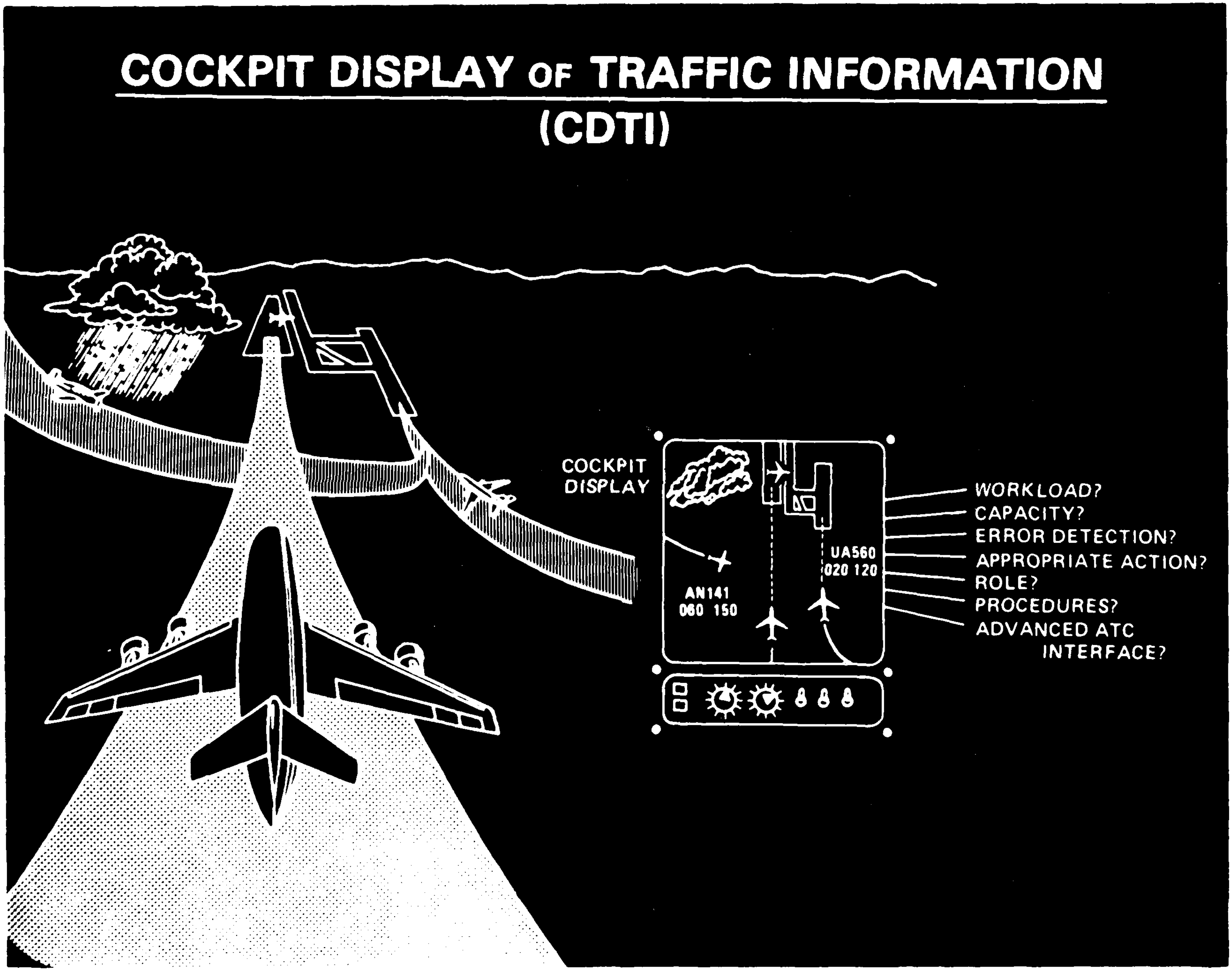
We've also discovered that the vertical situation is significantly more difficult for the pilot to assess and understand than horizontal situation and some of our experiments that are coming up in a couple of months are designed to try to improve the symbology in the aiding that we give to the pilot in the vertical dimension so that we can make it simpler for him to understand what his vertical situation is relative to another airplane. We've also discovered that the geometry of the en-

counter is extremely important. As I mentioned, straight line encounteres are much simpler for the pilot to work with, than are maneuvering encounters. Horizontal situations where there is some altitude separation are much easier for him to work with than are vertical situations where he has a vertical closure rate with another airplane. Closure angles that are closer to head-on give significantly higher error rates than closure angles that are closer to tail chases, mainly because of the slower closing velocity. The information as displayed to the pilot is extremely important. Predictive information is much more important and gives better performance and is preferred by the pilots over history information. Predictive information that is based on turn rate, bank angle and airspeed is much more effective than predictive information that is based on heading or track. Speed information, climb and descent arrows, the status of the other airplane relative to ATC (that is to say whether he is IFR or VFR) and whether he is a CDTI equipped airplane or not, all has turned out to be relatively unimportant information.

Now that is for the separation function. When you are trying to space yourself on another airplane the ground speed information becomes very important. Pilots have preferred distance based spacing cues over the time-based cues. Display clutter is a significant problem, and information coding does not solve the clutter problem alone.

Finally so far, at least in our experiments which are in a very preliminary stage, we have not seen an adverse affect of having CDTI in the cockpit on the pilot's traditional piloting duties. We have not seen any blunders in the cockpit or frustration on the part of the pilot or any kinds of glaring errors that occurred. We have, however, seen that the workload does go up and that the pilot tends to let his performance using the CDTI start to slip as his workload relative to operating his airplane goes up. In other words, the single sigma values for how accurately he's spacing himself on another airplane increases as he gets closer to the runway, as his workload flying the airplane goes up.

That's kind of a summary of where we are in the CDTI program. Thank you.

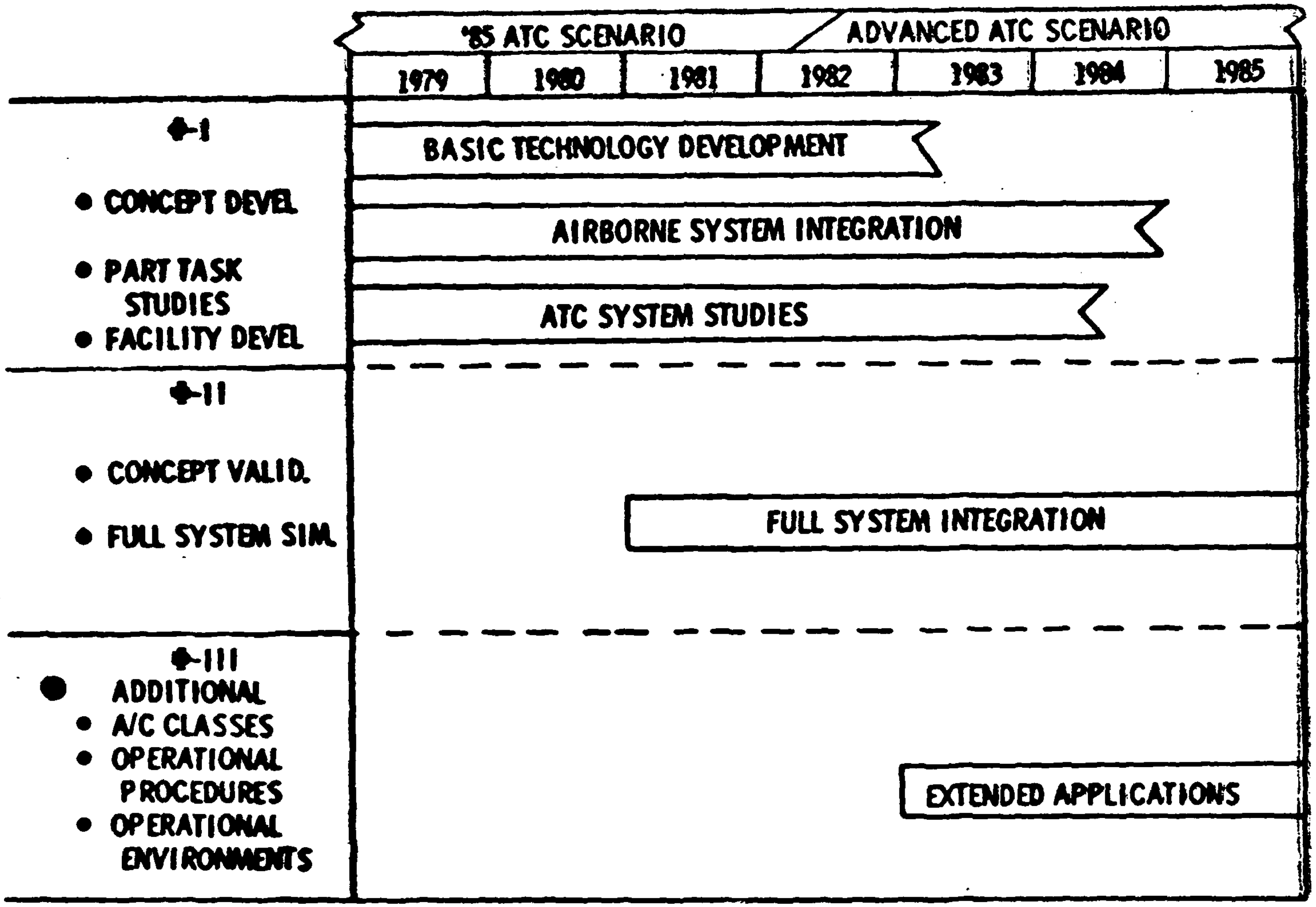

COCKPIT DISPLAY OF TRAFFIC INFORMATION
(CDTI)
COCKPIT
DISPLAY
AN141
060 150
UA560
020 120
WORKLOAD?
CAPACITY?
ERROR DETECTION?
APPROPRIATE ACTION?
ROLE?
PROCEDURES?
ADVANCED ATC
INTERFACE?

THE CDTI PROBLEM

MANY YEARS OF RESEARCH HAVE INDICATED THAT THE CONCEPT OF GIVING THE PILOT INFORMATION ON SELECTED TRAFFIC OF CONCERN MAY HAVE POTENTIAL ADVANTAGES FOR IMPROVING SAFETY, EFFICIENCY, AND CAPACITY IN THE ATC SYSTEM. HOWEVER, RESEARCH TO DATE HAS NOT FULLY EXPLORED THESE ADVANTAGES, AND POSSIBLE DISADVANTAGES, IN AN OPERATIONALLY REALISTIC ENVIRONMENT.

FURTHER RESEARCH IS NEEDED BEFORE IMPLEMENTATION CAN BE CONSIDERED TO DETERMINE THE EXTENT TO WHICH PROJECTED BENEFITS AND LIABILITIES OF CDTI MAY TRANSFER INTO REAL-WORLD OPERATIONS, AND THE EFFECT CDTI MIGHT HAVE ON THE PILOT, CONTROLLER AND ATC SYSTEM CAPACITY.

CDTI PROGRAM PHASES



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NASA LANGLEY RESEARCH CENTER

PHASE I OBJECTIVES

SAFETY - 1. DETERMINE ABILITY OF PILOT TO DETECT ERRORS UNDER REALISTIC WORKLOAD.

2. DETERMINE IMPACT OF CDTI ON OTHER PILOT DUTIES.

3. DETERMINE WHETHER A PILOT HAVING CDTI INFORMATION WOULD TAKE UNJUSTIFIED UNILATERAL ACTION TO AVOID A PERCEIVED CONFLICT.

4. DETERMINE ABILITY OF PILOT TO RECOVER FROM A SEPARATION LOSS (SINGLE & MULTIPLE AIRCRAFT SITUATIONS).

5. DETERMINE ABILITY OF PILOT TO PROVIDE BACKUP SEPARATION IN VARIOUS ATC FAILURE MODES.

6. DETERMINE CONTRIBUTION OF CDTI TO PILOT'S ABILITY TO DETECT AIRBORNE SYSTEM FAILURES.

7. DETERMINE ABILITY OF CONTROLLER TO SPACE NON-CDTI AIRCRAFT IN MIXED ENVIRONMENT.

8. DETERMINE ABILITY OF CONTROLLER TO DETECT & CORRECT AN ERROR BY A CDTI AIRCRAFT.

PHASE I OBJECTIVES

CAPACITY -

1. INVESTIGATE THE DEGREE OF SPACING ACCURACY ACHIEVABLE BY PILOTS AND CONTROLLERS FOR NORMAL AND LESS THAN NORMAL SPACINGS IN IMC/VMC CONDITIONS.

2. INVESTIGATE THE SPACING STANDARDS THAT A PILOT HAVING CDTI IS WILLING TO ACCEPT IN IMC/VMC CONDITIONS.

3. INVESTIGATE WHETHER FLOW STABILITY IN MIXED AND UNMIXED TRAFFIC FLOWS IS A PROBLEM AND, IF SO, HOW DAMPING CAN BE PROVIDED IN IMC/VMC CONDITIONS.

4. INVESTIGATE THE SENSITIVITY OF TRAFFIC FLOW RATE TO CDTI EQUIPAGE RATIO FOR SIMILAR AND DIFFERENT PERFORMANCE CLASS AIRCRAFT IN IMC/VMC CONDITIONS.

5. INVESTIGATE COMPARATIVE ABILITIES OF PILOTS AND CONTROLLERS TO MERGE AIRCRAFT FROM TWO DIFFERENT STREAMS OVER AN ARRIVAL FIX.

6. INVESTIGATE THE CONTRIBUTION OF CDTI IN INCREASING OR DECREASING PILOT ACCEPTANCE OF VARIOUS LEVELS OF ATC AUTOMATION.

7. INVESTIGATE THE IMPACT OF CDTI IN INCREASING OR DECREASING OVERALL ATC SYSTEM PERFORMANCE.

PHASE I OBJECTIVES - (CONT'D)

EFFICIENCY -

1. DETERMINE IMPACT OF CDTI ON PILOT'S ABILITY TO EXECUTE A MORE FUEL AND TIME EFFICIENT APPROACH.

2. DETERMINE IF CDTI IS FELT BY PILOTS TO BE A NECESSARY PRE-CONDITION FOR ACCEPTANCE OF ATC AUTOMATION.

3. DETERMINE WHETHER CDTI INCREASES OR DECREASES VOICE COMMUNICATIONS.

4. DETERMINE CONTRIBUTION OF CDTI TO PILOT'S SITUATIONAL AWARENESS.

5. DETERMINE CONTRIBUTION OF CDTI TO IMPROVED ATC CLEARANCE COMPREHENSION AND VERIFICATION.

SOME POTENTIAL PASSIVE CDTI FUNCTIONS

FUNCTION/USE	POSSIBLE BENEFITS	POSSIBLE PROBLEMS
Situational Awareness	*Replaces mental image *Pilot assurance *Improved wx. avoidance *Improved reaction/ recovery from emergencies *Reduced voice communications *Clearance compre-hension *Improved planning *Awareness of VFR aircraft *Efficient transfer of info *Visual acquisition	*Scaling problems *No knowledge of intent *No knowledge of strategy *Contesting clearances *Increased pilot response time in emergencies *Increased voice communications *Inefficient transfer of info *Deliberate abuse *Different data sources
Blunder Detection and Recovery	*Avoidance of CAS maneuvers *Monitoring of clearance execution by other pilots *Monitoring of controller actions *Runway incursion protection	*Increased workload *Distraction from other duties *No knowledge of intent *Reduced visual scanning *Ability to detect blunders
Reductions of Separations	*Closely spaced parallels *Runway occupancy mon. *Intersection runway use *Enhancement of other systems *Pilot confidence	*Increased pilot workload *Distraction *Reduced scanning *Interference with other systems
Hardware Failure Det/Rec.	*Airborne failure det. *Groundside failure det. *Protection during transients *Recovery from failures	*Discrimination/ isolation of failures
Automation Monitoring	*Reduced ground redundnacy *Backup to controller mon. *Pilot confidence	*Pilot workload *Distraction

SOME POTENTIAL CDTI ACTIVE FUNCTIONS

FUNCTION/USE	POSSIBLE BENEFITS	POSSIBLE PROBLEMS
Spacing and Merging	*Improved delivery accuracies *Reduced controller workload *Enhancement of automated systems	*Increased pilot workload *Increased controller workload *Interference with automated systems *Flow stability
VMC Patterns in IMC	*Increased IMC capacity *Reduced noise *Reduced fuel usage *Reduced low altitude exposure	*Decreased VMC capacity *Workload *Stabilization during approach
Conditional Clearances	*Reduced controller workload *Reduced clearance restrictions *Reduced airspace protection requirements *Improved flight efficiency	*Increased pilot workload *Increased airspace protection requirements *Increased controller workload
Primary Separation	*Reduced ATC costs *Improved path and profile flexibility *Reduced flight plan requirements *Improved flight efficiency *Reduction of separations in oceanic airspace	*Handling of unequipped aircraft *Secondary conflicts *Coordination when ATC also active
Airport Surface Operations	*Reduced controller requirements *Reduction of runway occup. *Reduced fuel consumption	*Mexican standoffs *Poor flow control
Collision Avoidance	*Reduced need for CAS *Enhancement of CAS operation	*Judgement of situation *Selection of right maneuver *Response time *Secondary conflicts

CDTI RESEARCH CURRENTLY UNDERWAY

FAATC - ATC/CONTROLLER PRELIMINARY IMPACT STUDY
- G/A CDTI BASELINE STUDIES
- PLANNING FOR INTERMEDIATE FLIGHT TESTS
- PLANNING FOR DEDICATED FLIGHT TESTS (WITH LRC)

LANGLEY - SENSOR NOISE STUDY
- GROUND SPEED RESOLUTION STUDY
- PREPARATION FOR L-1011 CDTI FLIGHT TESTS (LOCKHEED CONTRACT)
- CDTI PROCEDURES STUDY (SCI CONTRACT)
- FLOW STABILITY ANALYSIS (AMA CONTRACT)
- PLANNING FOR DEDICATED FLIGHT TESTS (WITH FAATC)

AMES - ELECTRONIC VFR STUDY
- PLANNING FOR CAS/CDTI INTERACTION STUDY

HAV/1-5-81

CDTI RESEARCH STUDIES COMPLETED

LANGLEY - TCV PRELIMINARY FLIGHT TEST

- TIME/DISTANCE SPACING CUE STUDY
- DISPLAY SIZE STUDY

AMES - CDTI SYMBOLOGY PREFERENCES STUDY

- DYNAMIC SYMBOLOGY STUDY (HORIZONTAL SITUATION)
- DYNAMIC SYMBOLOGY STUDY (VERTICAL SITUATION)

AUTOMATED TERMINAL SERVICE

Edmund J. Koenke

Federal Aviation Administration

I hope you've all had an opportunity to see the ATS/APAS film this afternoon. This is another example of very close cooperation between NASA and FAA on aviation programs. I'm going to talk about the ATS Program and then Jack Parks from NASA will talk about the APAS Program.

These programs are important because they provide pilots with additional information to aid in the assessment of the airport traffic situation. They may also be included in the concepts that could emerge from this Work Shop.

During the next several decades, our projections show that quite a few airports will become eligible for manned control towers. These are expensive to install, operate and maintain. We then decided that it would be worthwhile to investigate an automated alternative to a tower which could provide traffic advisories, sequencing, and other services normally provided by a VFR tower. ATS would provide these services until criteria for a manned tower were met. We also wanted to investigate the possibility of providing services to enhance safety, particularly at low activity General Aviation Airports.

We have a problem today and it is projected to increase in the future. Today there are 905 busy airports. The most recent forecasts by the Office of Aviation Policy predict that by 1990, 70 non-towered airports will have sufficient traffic to qualify for tower installations, and that 60 of the existing towered airports are expected to reach saturation. Saturated airports cause delays and diversion of traffic to other airports, resulting in increased costs to the users, and inconvenience and cost to the passengers. Compounding the situation is the fact that deregulation is causing a shift in traffic routes and densities.

Speaking from the safety standpoint between 1964 and 1978 there were 309 mid-air collisions. The preponderance of these accidents, 215 to be exact, occurred where at least one aircraft was in the traffic pattern. 172 of these were at non-towered airports. To put this in perspective these 172 accidents could have occurred at any one of 13,000 airports. Obviously, it is a fairly random event which means you can't predict the airport where you are going to have an accident. There doesn't seem to be any correlation between the level of traffic and when or where an accident will occur. So as a safety device, ATS may have little impact on the overall accident rate even though at specific airports it will provide some safety benefit. Any system such as ATS and APAS suffer the same limitations unless you put one at every airport. That would become a very expensive project.

We've also looked at a number of alternatives for improving terminal safety and reducing the operations and maintenance costs of a manned tower. We've looked at modified procedural systems, self-announce on UNICOM and self-announce on discrete frequencies. We are investigating how many frequencies would be available in the 25 KHz and 50 KHz VHF communication spacing environment in order to assign discrete frequencies to airports and to determine if that yields a significant safety enhancement. Radar advisory systems are being examined as a possible alternative. One potential system is a traffic advisory service based on skin tracking radar, which is basically the NASA approach. The FAA approach is a traffic advisory service based on a cooperative beacon system along with self-announce for non-Transponder equipped aircraft. Two other possibilities are: (1) a combination of the above two approaches and (2) a beacon-based system which assumes essentially total equippage of the entire aircraft fleet.

The FAA chose to examine the feasibility of the system relying on a cooperative beacon coupled with self-announce. The basic elements of the system that FAA developed consisted of an ATCRBS surveillance system, a data processor, a mini-computer and an FAA developed voice response system. On the airborne side the required avionics were a VHF radio and a 4096 code Transponder. An altitude encoder was not required for the minimum service available for ATS. An example of an available service is conflict prediction within an airport traffic area. In this situation if one or more aircraft are without an altitude reporting capability, the aircraft in horizontal conflict are assumed to be at the same altitude and a traffic warning is given to each aircraft. Naturally, if both aircraft have an altitude reporting capability, the actual altitude information is used.

As designed, ATS was a system to be used during Visual Meteorological Conditions. However, consideration was given to what would be required to interface it with the IFR system.

Now I'll give you a brief description of how ATS worked.

When an arriving pilot was within 10 to 15 miles of the airport, he would request ATS service by selecting a specific Transponder code. The computer would recognize this specific code, and request that the pilot "log-in", using his VHF radio. The "log-in" would consist of the pilot giving the aircraft identification number, aircraft type or whatever designation that the pilot wanted to have for message identification.

The computer would then give a discrete code assignment to that aircraft and the ID would be associated with the track established on the aircraft squawking that code.

As the pilot flew into the terminal area around the airport, the aircraft would be monitored, as well as all other beacon equipped traffic, and would be given automatic traffic advisories. The pilot would also be given some information with regard to where other aircraft were in the pattern. (With all aircraft equipped, a pilot could be given sequencing information as well). We also had some special services, such as a position fix service, where the pilot could dial up a special code on the Transponder and the computer would provide the bearing and range to the airport. Some pilots found this to be a significant help.

We tested these services during a public participation feasibility demonstration at Miller Park Airport at Toms River, New Jersey. We tested the log-in procedure, threat detection, and advisory services and provided automatic ATIS information which included winds and active runway. We tested the traffic pattern management service and provided general information on unidentified aircraft in the pattern. We also tested some services that responded to the pilots' special requests, such as position fix, and log-in confirmation. We also could check out his Transponder by giving an altitude readout if the aircraft was Encoder equipped. We obtained comments from the flying public on their evaluation of these services and to gain some insight as to what the system design should be in order to meet the user needs and desires. These tests were conducted from August 25 to September 30, 1979.

There were about 60-pilots who took part in the demonstration including some of the participants of this Work Shop. They flew about 140-flights and 25-pilots provided comments through an informal interview process. We also received additional comments from participants such as AOPA.

The pilots generally agreed that they found the system fairly easy to use, and that the information was helpful and accurate. They found the position fix to be the best feature. Sequence advisory messages turned out to be the least useful. The primary problem with that service was a loss of confidence when non-Transponder equipped aircraft were in the pattern and the automated terminal service said you are observed number two to the runway, while you observed three or four aircraft preceding you. There was serious concern expressed over lack of information on non-Transponder equipped aircraft, particularly for the conflict and the traffic advisory services.

We believe that we successfully demonstrated that it was feasible to provide automated services at an airport, but there is an obvious requirement for Transponders in a beacon-based system. Using primary radar, or coupling the secondary and primary together to try to get the best of both worlds have been mentioned as alternatives, and soon you will hear about what NASA was able to do with a primary radar system.

That's basically where we are. We're planning a program which will couple the best features of both systems. Even that doesn't come for free. A primary radar system that can do the kind of job that's necessary in providing traffic advisories, particularly conflict advisories, isn't cheap. Nevertheless, we are starting to examine how we can design a primary radar coupled with a secondary radar that would have the features and accuracy that are necessary to support this service.

AUTOMATED PILOT ADVISORY SYSTEM

John Parks

NASA - Wallops Island

Bascially the APAS concept is that low cost automated systems could provide airport and traffic advisory information at the nation's high density airports. An experimental APAS system was developed by NASA to test this concept. The system was initially tested at NASA and then this past summer it was moved to the Manassas Municipal Airport to test the system in an operational environment.

The APAS system has four basic design requirements. First, the system was designed to be low cost and affordable to most of the thousands of municipal and privately owned airfields in the United States. When the system was originally developed in 1975 a cost limitation of $50,000 was imposed. Today we're probably talking in the neighborhood of $80,000 for an APAS system. The second requirement was for the APAS to provide two basic services; the issuance of an airport advisory, and a traffic advisory message. The airport advisory message is broadcast once every two minutes and contains the favored runway information, the altimeter setting, and the ambient and dew point temperatures. The system was required to automatically select the favored runway from an algorithm that is a function of the prevailing winds, and would automatically perform fault checks. The system was also required to have what we call an operator control panel from which manual control over runway selection and weather sensors could be exercised. Additionally, the airport advisory system was required to be designed so that additional sensors could be implemented into the APAS as they become available.

The primary service is the Traffic Advisory Message. When we started the APAS program we thought about doing conflict alert, but analysis we performed utilizing the expected errors in the APAS system plus the way people fly indicated that this system would be in an alert mode approximately 30%

of the time. We realized very quickly that the system could not do conflict alert or people were going to have to change their method of flight. So a different approach was taken in that, if we could generate a mental picture in the pilot's mind as to where the traffic exists in the area, then the pilot could mentally filter thru the various traffic reports that were issued and pull out those aircraft reports that would be in conflict with him. In order to do this we decided to devise a system that would issue a complete traffic advisory report once every twenty seconds and this report would include the number of aircraft on each of the pattern legs and the range, heading and bearing of all non pattern type aircraft. Additionally, the traffic advisory system would utilize a skin tracking primary radar so no cooperation between the aircraft and the system would be required.

The APAS has several different coverage requirements: it has a broadcast coverage radius of about 20-miles, a radar coverage radius of five Nautical Miles and it was required to track all aircraft within three Nautical Miles of the airport. The three Nautical Mile limit was predicated on analysis which defined the radius that the traffic pattern can extend from the airport. This analysis indicated pattern distances of one and one-half to two miles for low performance aircraft, and two and one-half miles for high performance aircraft. The third requirement was for the system to have height finding capabilities and broadcast messages on ten aircraft and maintain track on twenty aircraft. And finally, the fourth requirement was that the interface between APAS and the pilot would only be thru a VHF radio where the pilot would tune his radio to the APAS frequency and receive both airport and traffic advisory messages.

The configuration of an APAS to meet these requirements has four basic elements. The system has a radar set and two computers; the first computer detects and tracks aircraft and performs pattern classification; the second computer processes the weather sensor information, selects the favored runway and issues the traffic and airport advisory messages. Additionally, the system has weather sensors and a VHF transmitter. The fixed base operator box in the View Graph is our operator control panel in which we exercise manual control over the system.

Now I am going to show you the actual configuration of the system that was tested at Manassas. The first feature is that the system was housed in a 40-foot trailer although we did not need that much space for an APAS. An ideal radar for an APAS system would be one that would elminate the ground clutter which

is our primary concern and really is one of the cost drivers in an APAS system. You can eliminate it by going to an MTI or Doppler type system, but analysis we did on radar types indicated that MTI or Doppler Radars were either cost prohibitive or they had insufficient range capability. We were therefore forced to go to a noncoherent marine pathfinder radar operating in the clutter environment. One of the clutter suppression techniques which we employed was the screen wire which allowed us to achieve approximate 30 db signal attenuation in the ground plain. This screen wire was sized so that it would attenuate both transmit and receive signals which occurred below approximately plus two degrees elevation angle.

Four weather sensors were mounted on a pole at the site; an anemometer, a barometer, and two temperature probes.

The height finding capability of the system was achieved in a somewhat unique way. The system utilized a single transmit and mulitiple receive antenna. The receive antennas were set at different elevation angles and we would take a 360 degree scan thru one receive antenna and then switch up to the next one. We maintained a single transmit antenna so that we would not have to go to high power switches on our antenna which are available but they do cost quite a lot of money. The antenna configuration that we used at Manassas is two dishes and a flat plate antenna. In the initial configuration of the APAS we used five of the flat plate antennas. These have a 13 degree beam width and just before the Manassas move we decided that the beam width for the lower antenna was too great and we had to switch to dishes to achieve a narrower beam to reduce ground clutter. This was a second method that we employed to reduce the ground clutter. Other methods that we used were individual STC controls on our receive antennas and also we developed computer algorithms to track in a clutter environment.

The equipment which is used in the experimental system is housed in three racks. In an operational APAS it would require approximately one and one half racks. The center rack contained our tracking computer for the experimental system. We expect that in an APAS system that this computer would be replaced with two microcomputers that are both physically smaller and cost a lot less. At the bottom of the third rack is a microcomputer which performed weather processing, runway selection, and generation of the voice messages. Just above that is an operator control panel and the final feature at the very top of the third rack is our radio that we used to broadcast our messages.

The maximum traffic density that the Manassas system was exposed to occurred on July 13. On that day the APAS operated at a rate exceeding sixty operations (landings plus departures) per hour for a period of three consecutive hours. The total track rate during this same period was seventy per hour. Also on that peak day there were approximately 250 occurrences in which two, three, and four aircraft were reported in one traffic advisory report. The data indicates that there were very high densities that particular day and that the APAS occasionally issued ten reports. Our data also indicated that there was one occurrence in which eleven aircraft were within our coverage area.

The performance of the APAS in high traffic density is one of the primary areas of investigation and we devised a method which, thru radar and visual observance, could verify each of the traffic advisory reports issued by the APAS system. A count of these was taken over a period of time twice daily. This data indicated that the APAS system demonstrated a 95% traffic report accuracy throughout the six week period. The five percent errors which occurred were analyzed and we discovered that about half of them were caused because of problems unique to Manassas. We had site location problems and, the week after we started the APAS testing, 37-large earth moving vehicles moved in and started to build a parallel runway. These vehicles produced some false reports.

The evaluation of the APAS system in the high traffic density for the day of July 13, indicated that there was no degradation in the APAS system. In fact the highest accuracy achieved throughout our test period actually occurred on this particular day.

Another area that we evaluated was the performance of the APAS in marginal VFR conditions. In fog and haze we had no problem with the APAS. The APAS contains software which detects the existence of rain and this software was set so it would attempt to maintain track within the traffic patterns while deleting non-pattern reports. We had several days when we had isolated thunderstorms and the system performed very well and the rain detection software was responsible for it. We had two occasions where we had moderate rain throughout the area and we had to turn the system off because of numerous false reports. The key thing here is that the system is able to detect the rain condition and that additional software could be employed to issue messages that would indicate that traffic advisory services would not be available and advise pilots to revert back to self announcement on UNICOM.

We notices that there was a significant decrease in the UNICOM voice traffic for the Manassas area whenever APAS was operating. We feel that this may be a key point because one of the problems in an operational APAS is to obtain the necessary frequencies. One thing you need to remember is that APAS uses a ground-based transmitter and the coverage area only needs to be 15 to 20 miles. But you do need to have frequencies for these different airports that would use APAS and if there is a significant decrease in UNICOM traffic it could be possible to consolidate more airports onto a common UNICOM and use some of the freed up frequencies for an APAS system.

The only system anomaly that we observed in Manassas was in the runway selection algorithm which we readily detected the first day. During light and variable wind conditions the APAS system switched the favored runway three times within a five minute period. We ended up with several aircraft taxiing back and forth trying to get off. This generated several nasty comments about the APAS system but anyway we recognized what the problem was and we were able to fix it within a matter of hours and the runway selection system was utilized for the rest of the test period.

The conclusions that we at NASA have come to from our Manassas testing are several. The first is that, as a minimum, we feel that the Manassas testing did demonstrate that automated systems can provide air traffic information and that pilots can utilize this information to increase their safety. A pilot's evaluation as to whether they would prefer an APAS system over a self-announced system indicated that they prefer an APAS better than four to one.

The two main areas that we feel that improvement can still be made in an APAS type system are clutter suppression and system delay. In clutter suppression we feel that there are several techniques that still could produce improvement. These include increasing the height of our radar antenna (the antenna at Manassas was at a 15-foot height).

We have looked at some low cost towers and we could possibly put it up about 50-feet. One other area is that we did not get a chance to engineer both transmit and receive antenna patterns for APAS. In particular, we feel the transmit antenna should be changed to a co-secant square antenna to decrease the amount of energy that we are pointing at the ground.

The problem with system delay is that we sweep through our antennas one at a time using a two second scan cycle for each, which gives us six seconds for a complete update of the track. This produced several effects. In acquiring an aircraft and bringing him into the system, we require three correlated radar returns before we would designate that track as being valid and start announcing him. Three correlated hits means 18 seconds before an arriving aircraft would be announced by APAS. There were several cases where high performance aircraft penetrated to within two miles before we got them into the system and started announcing them. Remember, the original objective was covering everybody within three miles. One other feature that this delay produced is that aircraft that went into a turn or had just previously made a pattern turn would be invariably reported on the previous pattern leg. Initial users of the system did not like this feature. They could identify themselves and they knew they had already turned base leg when APAS said they were on downwind. The system did perform consistently so that people who continually used it got used to this feature and it presented no problem to them. There are several ways of taking care of this delay and one that we have proposed is a multiple receiver radar. Our talks with manufacturers of radar indicated that the cost impact of this plus the cost impact of the antenna changes that we are talking about would be minimal for an APAS system.

The reduction in the UNICOM voice traffic is an area that should really be looked at for potential solution of the frequency problems. We had no way of quantitizing what was happening but it was readily apparent during the testing because approximately every two hours we would have to turn the APAS system off to save our tracking data. Whenever we did this the UNICOM voice traffic would pick way up when APAS was not operating.

The final recommendation is that a Phase Two Program be initiated to go ahead and solve both the delay and the clutter suppression. We feel that by doing those two improvements and then retesting the system, an APAS system would prove valuable for your uncontrolled airport world.

NASA

WALLOPS FLIGHT CENTER
WALLOPS ISLAND, VIRGINIA

AUTOMATED PILOT ADVISORY SYSTEM TEST AND EVALUATION AT MANASSAS MUNICIPAL AIRPORT

DE-SQAEB

OCTOBER 1980

DESIGN REQUIREMENTS

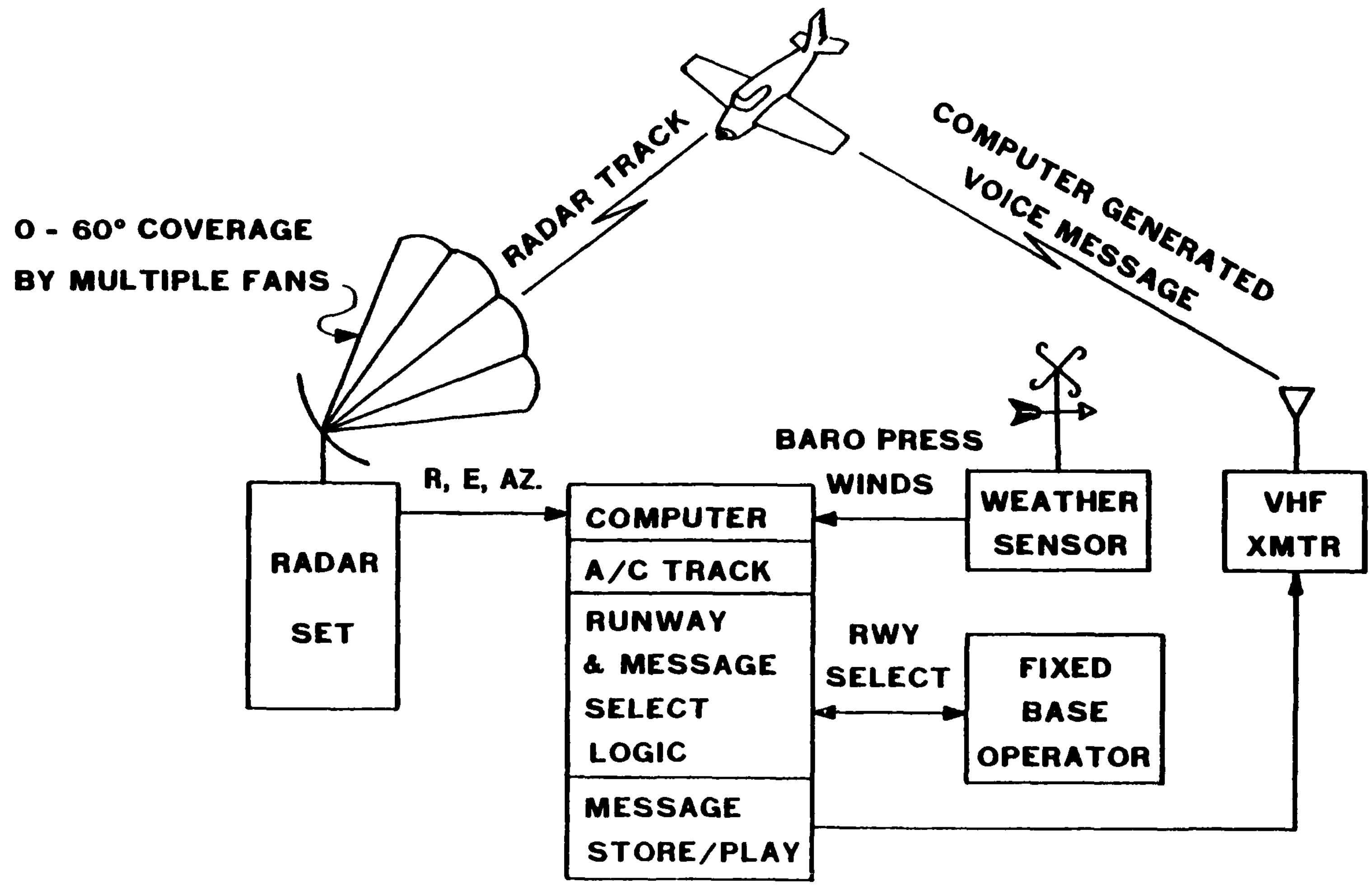
- LOW COST

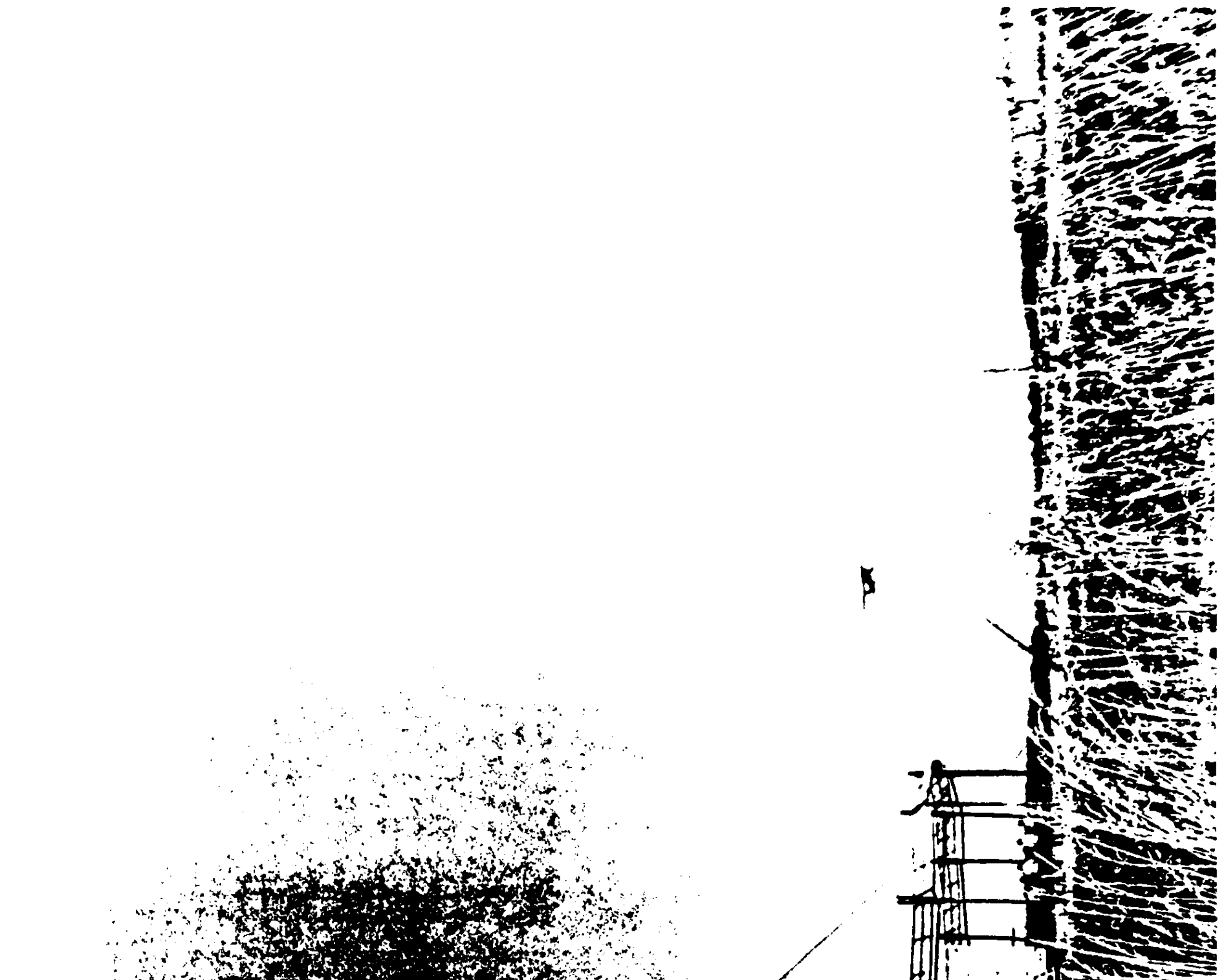
- AIRPORT ADVISORY SYSTEM
  - AIRPORT IDENTIFIER, GMT, RUNWAY, WIND SPEED, DIRECTION AND GUST, ALTIMETER, TEMPERATURES
  - RUNWAY SELECT AND SENSOR FAULT CHECKS
  - OPERATOR CONTROL PANEL
  - ADDITIONAL SENSORS

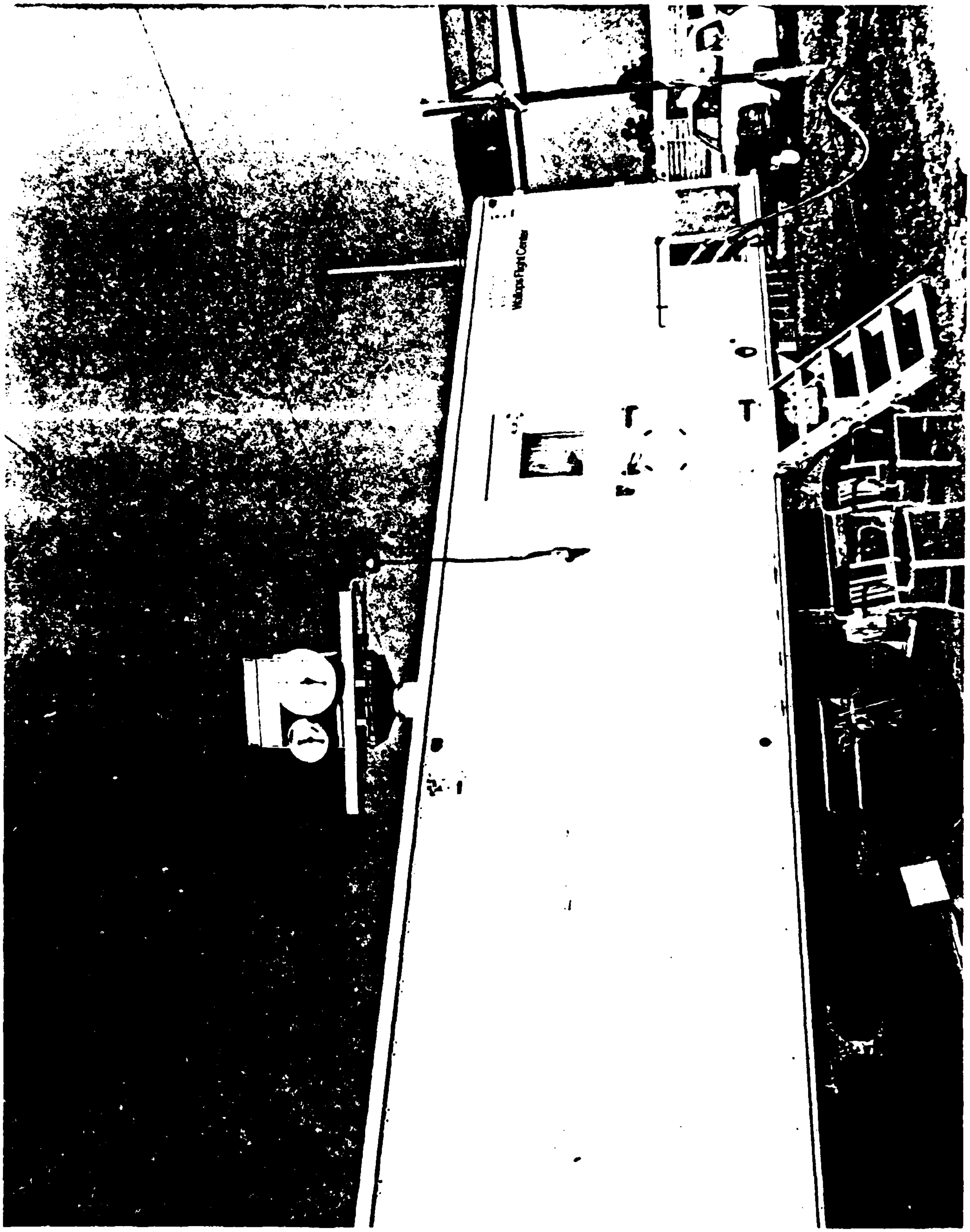
- TRAFFIC ADVISORY SYSTEM
  - 20 SECOND REPORTS
    - PATTERN AIRCRAFT
    - NON-PATTERN AIRCRAFT
  - SKIN TRACKING RADAR
  - COVERAGE
  - HEIGHT FINDING CAPABILITIES
  - REPORTS 10 AIRCRAFT AND TRACKS 20 AIRCRAFT

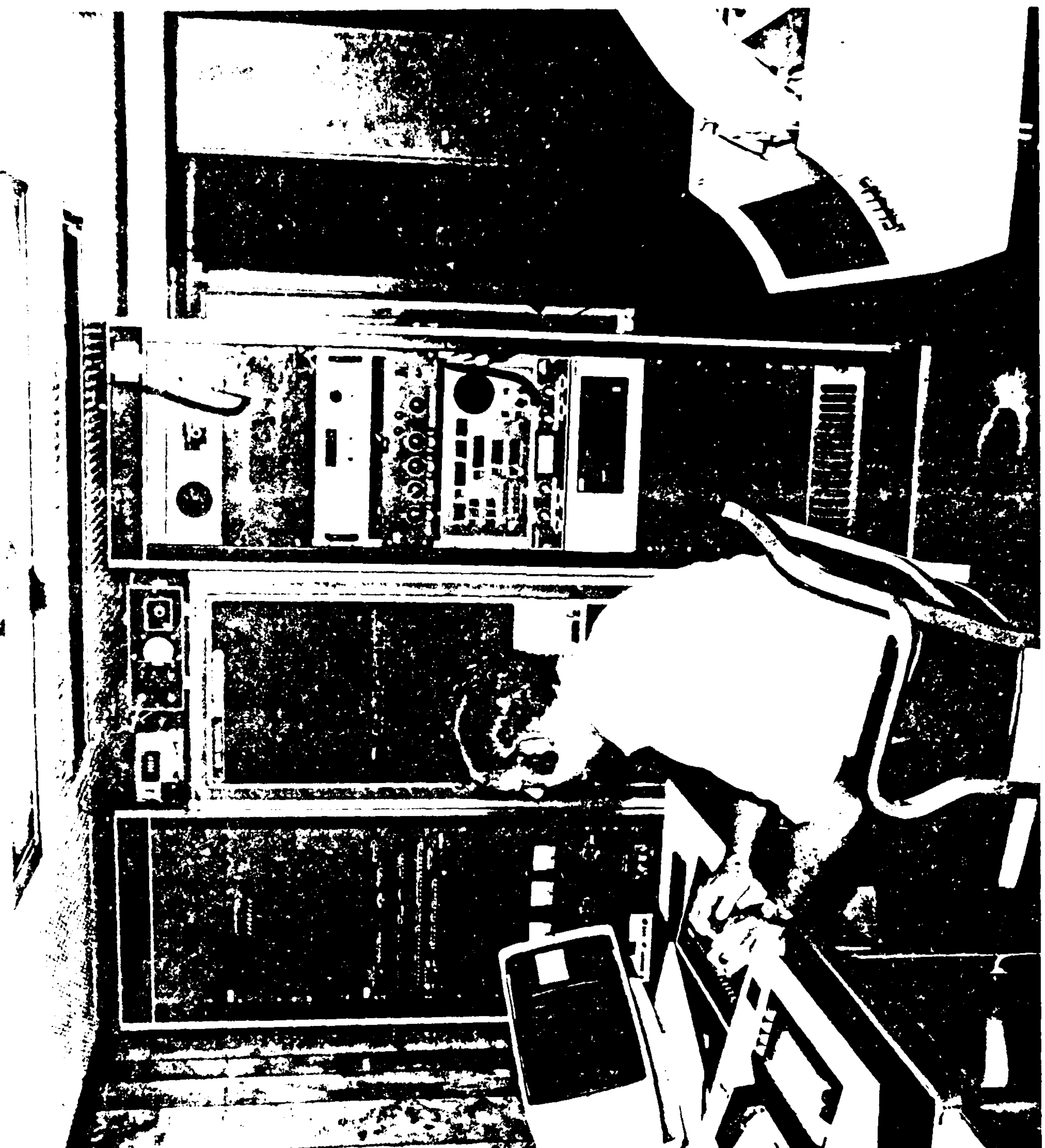
- VHF RADIO INTERFACE

AUTOMATED PILOT ADVISORY SYSTEM





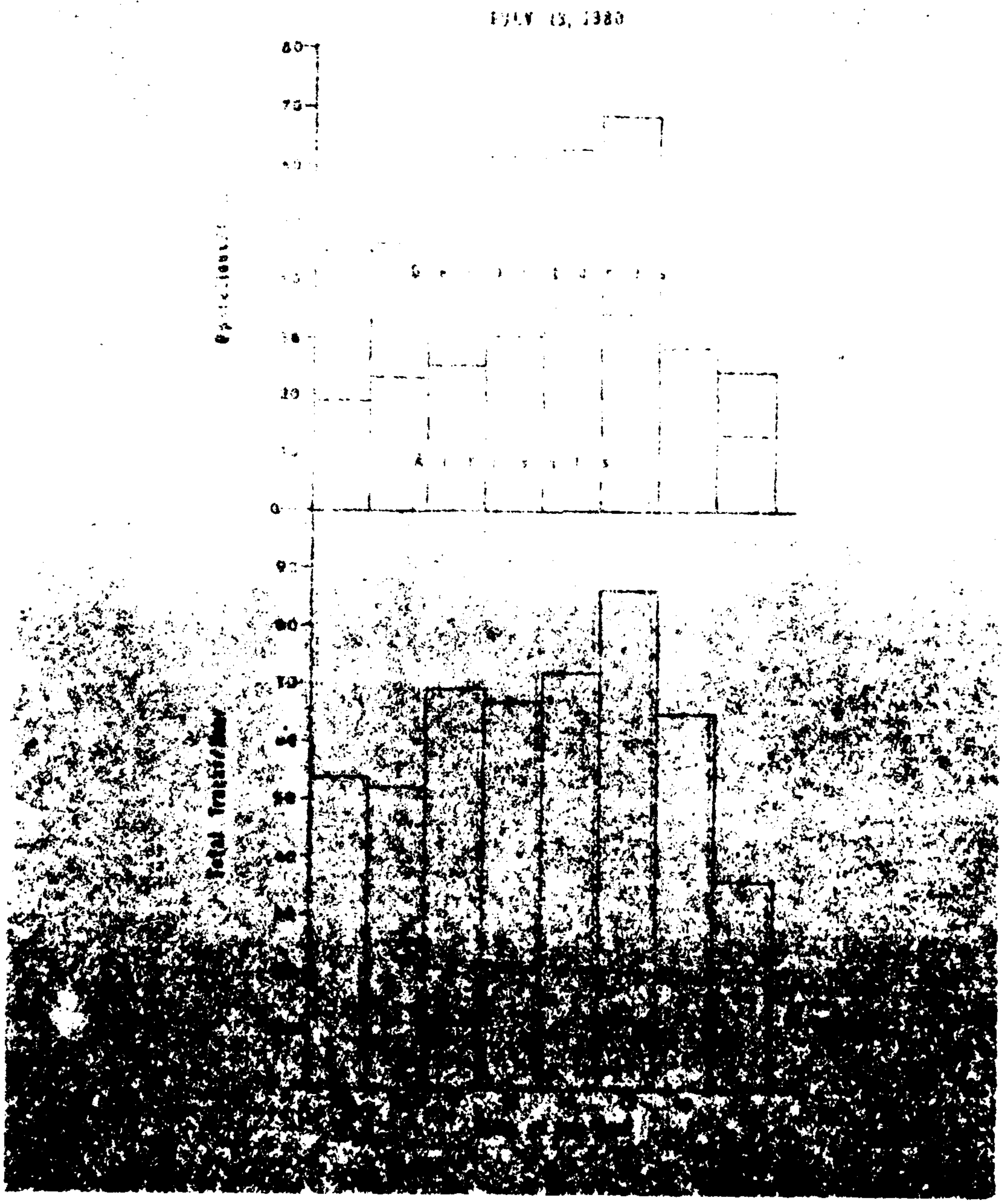

Wallops Flight Center



PERFORMANCE EVALUATION

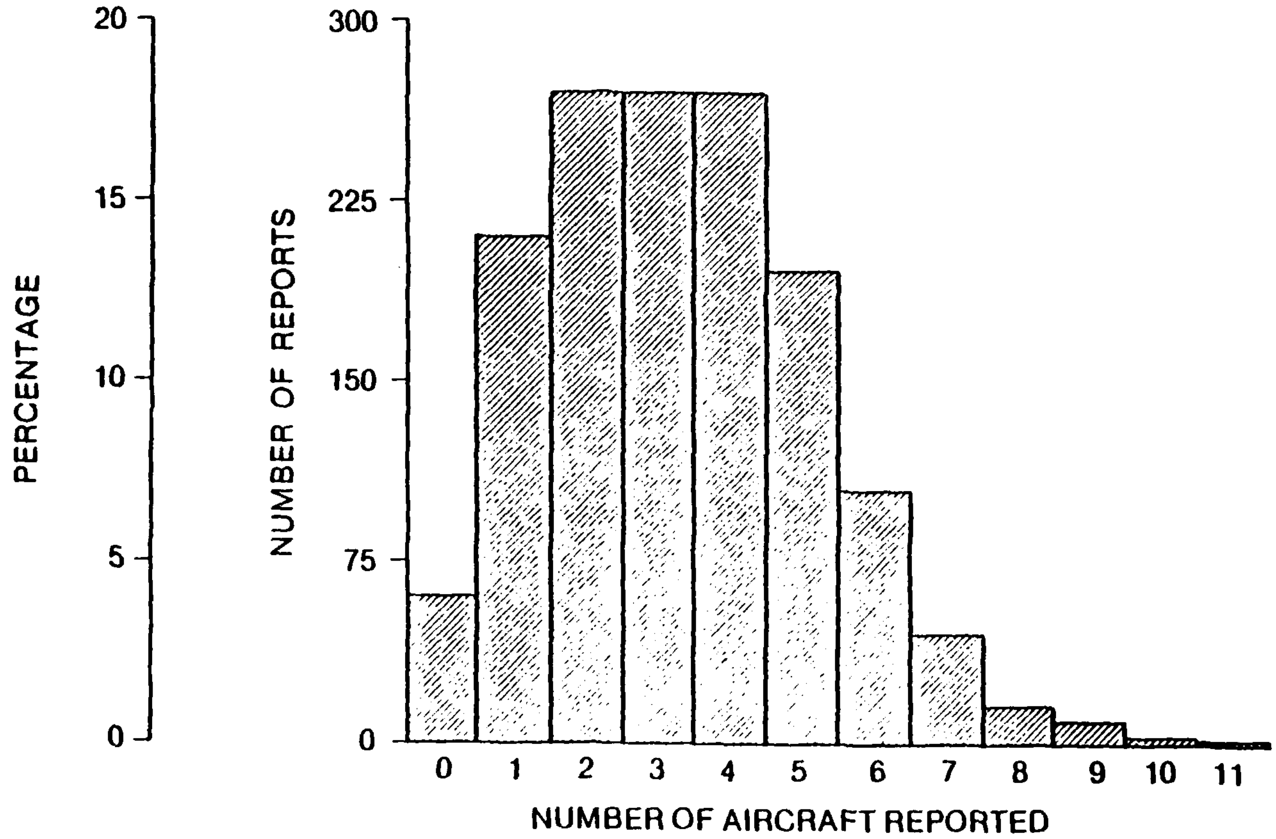
- METHOD
- 95% TRAFFIC REPORT ACCURACY
- NO DEGRADATION IN HIGH TRAFFIC DENSITY
- MIXED PERFORMANCE IN MARGINAL VFR CONDITIONS
- TRAFFIC ADVISORY REPORTS DELAYED 7 TO 17 SECONDS
- REDUCTION IN UNICOM VOICE TRAFFIC
- RUNWAY SELECTION ANOMALY

TOP HORIZONTAL



TRAFFIC REPORT HISTOGRAM

JULY 13, 1980



CONCLUSIONS

- PROVED CONCEPT FEASIBILITY AND PILOT PREFERENCE

- ADDITIONAL AREAS OF INVESTIGATION
    - CLUTTER SUPPRESSION
    - SYSTEM DELAY
    - REDUCTION IN UNICOM VOICE TRAFFIC

- PHASE II

FINAL DISCUSSION

OPENING PLENARY

Mr. Quinby - We've got time for another session of questions to the presenters on matters of clarification of anything that is not clear; that you need more expansion, clarification or understanding.

Mr. Hollister - I want to ask Ed Koenke - on your slide it said something was being introduced into ATARS but you didn't say anthing about it, could you expand on that?

Dr. Koenke - We have some work going on with the MITRE Corporation taking a look at the methods of providing ATARS service to aircraft in the traffic pattern. And we're using some of the fundamental principles that we used before for ATS, in order to provide that service. We use a pattern classification logic which says whether the aircraft is downwind, base or final and puts lead into the system. One of the points that's made here is that it's pretty hard to track around the corners, especially when you're pulling pretty tight turns. So we build lead into it, betting that they will be turning in a given part of the airspace and carry two tracks at the same time. We're testing these concepts with data that we have from Houston and from Hobby Airport.

Mr. McComas - I don't know whether this is a comment or question to Harry Verstynen. It had to do with his concluding remarks about proving that you couldn't use a CDTI as a CAS. I heartily agree with the thesis that you shouldn't use a CDTI for a CAS, I don't think that the tests that he ran prove anything except that ATARS will provide a CDTI that will make a CAS. But with a BCAS with a high data rate - not the four second data rate that was used in the test but a one second or a half second update - you don't have that limitation.

Mr. Quinby - I'm sure that and other things will be expanded on tomorrow.

Mr. Barry - Harry you stated the objectives to your programs and they appeared to me to be critical issues that you're examining. What I'd like to know is where does the CDTI program fit? Is it going to result in certification standards for cockpit display systems? Will it come up with minimal performance standards, minimum equipment standards for some types of airspace operation? What is the policy objective of the program?

Mr. Verstynen - Everywhere I go I get one of these questions. I don't know, really. We spent hours in our planning groups speculating about the most probable way in which you're going to first see a CDTI come into existence and of course one of the possibilities might be a requirement as part of some kind of highly automated ground system as I mentioned earlier. But frankly I really don't personally see the FAA coming out with a requirement that says that a CDTI is a minimum equipment item for flight in certain kinds of airspace. As you've seen today, I think that the FAA's approach is to explore lots of alternatives so that you can provide levels of services in different kinds of airspace depending upon the kind of equipment that the pilot has in his particular airplane. So what we see right now as a more likely alternative is that a CDTI would first appear as some kind of evolutionary development off the CAS system. The basic difference between an ATARS display and the kinds that are being explored now for CDTI is really when you show the pilot the location of other data and what you ask him to do with that information. It's a very simple matter to change the algorithm in such a way that the pilot can now look at traffic out to say 12-Nautical Miles or 15-Nautical Miles as opposed to only having it within 2, 3 or 4 Nautical Miles of his own airplane. If that is the case, then our position may be one of having to initially certify that the existence of that information in the cockpit is a hazard to flight. And that's why we try to stress the passive functions of CDTI in our initial research so that should this event occur and CDTI starts to appear thru the normal processes by which equipment gets into airplanes that we've got as much data as possible to give to flight operations people to make some kind of decisions on certifying. Now once that data is accepted data some guy will come along and say "now I've got a CDTI and I can establish my own separation therefore I would like a credit against something". He would like to be able to follow another airplane to the airport or a lower minimum or something like that then a whole different group of people in the FAA get involved and the process gets a lot more complex. I don't really know whether we're talking about performance standards or what.

Mr. Quinby - Isn't it safe to say, Harry, that what you're doing is using a research tool for data collection and what you're surely not doing is establishing anything like a performance standard for this device at this early stage of the game.

Mr. Verstynen - I think that's accurate. We have no idea whether the advantages are going to outweigh the disadvantages to this kind of a concept or not. It may eventually become a moot point. The research may show that there are just so many different hazards associated with it that it's not worth the trouble.

Mr. Rupp - I have a question for Ed Koenke if I understand correctly on the ATS system when the pilots dials in a preset code, which I think must be determined for that particular station and later he is given information to change to another code, it seems to me that that code selection becomes a primary part of the system and must be included when we design DABS equipment.

Dr. Koenke - I believe that it's a very easy way to get into the system and the DABS Transponder does have the capability of dialing up an ATCRBS code. A block of codes can be set aside for a specific airport and will be on the chart for that airport and the dial up code might be 1500. Whenever the system would see that code it would know somebody is trying to log in. It would question who's trying to log in, and then assign a discrete code. The discrete code assigned might not be necessary with DABS, but the dial up to let the system know that you wanted to get into it probably will be. I haven't thought it thru totally but that's off the top of my head.

Mr. Quinby - While you're on your feet and off the top of your head how did you find out there were 905 busy airports?

Dr. Koenke - Very carefully. I'm not trying to evade it, I used Buige's viewgraph and I didn't find it out.

Mr. Quinby - It's a very interesting new development and we're here to learn new things.

Dr. Koenke - Well there could have been 906, Gil, I'm not quite sure.

Mr. Quinby - Well you'll have to tell us the actual date and time when the count was taken.

Dr. Koenke - You're right.

Capt. Berube - I think Bill Flener is still in the audience. Bill once mentioned the fact that the present Air Traffic Control System was really a very effective collision avoidance system; the first. I guess you might have said the second if you had considered the human eye. But the human eye has very considerable limitations of which we're probably all very aware. This is one of the reasons why I as an individual am very much a subscriber to the concept of CDTI. One of the statements that you made, Harry, almost rolled me over. The statement that CDTI is not a CAS based on the concept that a 16-second time frame experiment indicated that pilots were not able to resolve conflicts. I submit to you gentlemen an opinion and would like to ask Bil Flener to comment on this whether or not a 16-second viewing by an Air

Traffic Controller of a potential conflict first turn on to turn off would provide any better results than were encountered in the 16-seconds that the pilot had. I think even as Art has indicated that the ATARS or AERA system would have a very difficult time resolving a conflict accurately in a 16-second look, or about 4-hits. So I would like to ask Harry to retract the comment because I don't believe it to be true. I don't think you can reach that conclusion Harry, and furthermore I submit that it may turn out to be true but I don't think it is so far on the basis of the experiments that have been conducted. Secondarily, you went on to say as I understood it that the 52-second time frame provided a considerable improvement and I think Bill's answer to the question that I have asked would indicate that it is the nature of collision avoidance involving <u>any</u> display technique provided there is a human being in the loop. So could we hear from Bill and Harry as a retraction?

<u>Mr. Quinby</u> - Are we sure we want to go into this in depth at this point? We've got work to do and tomorrow is going to be available for this kind of discussion. I wouldn't expect Harry to back off that that easily.

<u>Mr. Flener</u> - I have a couple of questions anyway so I stood up and walked over here. But Capt. Berube is correct. I'll try to keep it short. For an aircraft controller or pilot or whatever, 52-seconds is more like it. When he asked me the question and we talked about it I would have gone back some seconds earlier, 50 or 60 seconds, before taking some action. Conflict alert was put in on a Thanksgiving evening; I put it in. I made them make up a system and bring it out. Conflict alert means you've already lost standard separation. When you've lost it the idea is to prevent a conflict climb or descent or whatever <u>immediately</u>. You've already lost separation. And that's something that a lot of people don't understand. They think that conflict alert was put in the system to prevent a conflict and that's exactly right, it was put in just to prevent a conflict not to assure standard separation in the system. Now my two questions and they are for Dr. Zellweger, who is quite familiar with what I'm going to ask because I always ask them. Why does it take so damn long? I appreciate OMB A-109, I appreciate Ed's problems, I appreciate budgeting and all that, but 1988 is a long, long time to live with the capacity of the system that we have today. Now there have been two meetings and I don't know the results of those meetings; perhaps you do Doctor. When you get into third party liability, and this is the second part of my question, third party liability which a lot of you haven't even heard of. IBM was the main contractor on the original 9020's and a battery of lawyers came into see me and Jeff Cochran and the big thrust was third party liability - Tennerife, Grand Canyon, that sort of thing. How should the equipment manufacturer insure himself?

What are his costs; how much is he going to reserve? Dr. Zellweger makes the point of five contracts in 1983. What five contracts or contractors are even going to bid when they get into this matter of third party liability. And IBM is working very studiously in trying to resolve that problem today. The question is can't we change A-109 and cut it down to three or four years to get at least that much off of it, to get it back to 1983, 84 or 85? I realize that that's pretty close, it's already 1981, but if we can do it we've got to get going on these computers.

Dr. Zellweger - I don't know if Frank is still here, he might be able to answer the question better than me. I don't think A-109 is what's taking that much extra time, we really don't. Now we've gone thru the calculations of what it takes in FAA to put together some sort of a statement of work to get it thru all the legal things that one has to go thru and that's how long it takes. We've tailored A-109 so that you do not waste time between the different phases. From start to finish the contractors are working towards final goals of getting a system in the field. And looking at it that way that's how long it takes, it is a big job. As far as the third party liability question goes, Bill, I agree with you unless that is resolved we are going to have a tough time getting the companies that have the qualifications to build the kind of system we want to bid, and I know that our Administrator and the Chief Counsel have been working actively trying to solve the problem. My guess is that there will be some resolution before we go out and actively try and solve it.

Mr. Quinby - Thank you Doctor. No, it just means the taxpayer's going to accept the liability. Harry; briefly.

Mr. Verstynen - I had planned to stay around for the whole conference in which case I'd just save my remarks for tomorrow or some other time, but something got screwed up in Washington so I've got to go back. Believe me I can screw things up by remote control or any other way but unfortunately I've got to go back tonight. So I'm not going to retract what I've said, however, I will offer just a couple of sentences of explanation. First of all I admit that that's very shaky data that that conclusion was based on, but it is the same conclusion that you come to by looking at some other work that's been done in visual collision avoidance and work that's been done at Lincoln Labs and other places. So it's not totally off the wall. The second thing is whether or not you agree with me is pretty heavily dependent upon what you define as CAS versus primary separation. Okay now for that conclusion what I'm talking about is that the CAS function is something that comes in after primary separation has already failed

and you are in danger of two airplanes actually touching each other in mid-air, and a maneuver has got to be made right now to keep these airplanes from touching each other. Now in that kind of situation I guess you could also interpret rationally that collision avoidance is that if you separate two airplanes by 12-Nautical Miles you've prevented a collision. So if that's your definition of CAS then that's inconsistent with what I said. I do believe, and our data has shown, that CDTI probably is useful for providing primary separation if the situation is not too complex; if you have fairly straight encounters, two airplanes on straight flight paths so that you're not really worried about lags and other traffic and all that kind of thing. If you're talking about separating airplanes by 5-Nautical Miles or 6-Nautical Miles or 4-Nautical Miles and you're talking about fairly simple encounters involving two airplanes and not multiple airplanes then the data that we have so far indicates that there's probably a function for CDTI in that area. And maybe that's what you call CAS. But if you let the situation develop to the point where two airplanes are about to hit each other and if you're talking about a maneuvering situation where one or the other airplanes is in a turn or climbing or diving or something you are talking about realistic kinds of radar noise jitter, lags and those kind of things, the data that we have so far indicates that the pilot is not a good judge of that situation. He may just as likely make a bad maneuver as a good maneuver. And he probably needs computer assistance.

Mr. Quinby - Thank you Harry.

Dr. Miller - I may be a little bit out of order, but I sense an interest in Active BCAS here in the conference today which I hadn't quite anticipated. I'd just like to let everybody know that there is going to be a conference on BCAS the 27th and 28th at the Dulles Marriott and I have a couple little slingers here in my pocket which I'm going to put up on the table in case there are folks here who are interested and have not received an announcement on the conference.

Mr. Quinby - Thank you very much. Can we get down to business on the Working Groups now? We have heard what I believe was a very concise, very appropriate smorgsboard of technology, status reports, and functions. It's not the purpose of this Work Shop to second guess, criticize or attack that technology necessarily. It is the purpose of this Work Shop to accept the reports as received and understood and to build on them. We are to produce a more positive definition of alternative separation concepts and provide FAA with direction that will permit FAA to explore these alternatives. We have accepted the challenge of doing that in a day's time. We don't have the luxury of the tangential

digressions of the E & D Initiatives Process or of any of the other long-term, long-running, late, late shows. That means we have to take what we now know about alternative separation concepts and advance it for approval of the final Work Shop Session on Friday and for publication in the Proceedings. Concise statements on Friday of definitive substance and constructive content would further justify attention and funding if alternative concepts could be graded; such as, "we believe that this has potential, and should be developed thus", or "we doubt that that has sufficient potential to justify further investigation".

We're coming at this challenging issue from two different points of view. And there will be a third. All three in their discussions deliberations and preparation of statements for the closing plenary will step on each other's feet. Inevitably. You cannot neatly separate procedural issues from the technical limitations. You cannot adopt a technical recommendation in complete ignorance of its economic consequences. You cannot recommend mandatory carriage of equipment in airspace without an idea of the benefits and the cost to the users of such a recommendation. So all three Working Groups tomorrow will interact and there will be some few of us who will wander around from group to group attempting to enhance the progress towards product of each of the groups.

Each Working Group will accept the responsibility of developing a report for the closing plenary session. The closing plenary will duly deliberate the reports of the Working Groups. And the verbatim transcript of the closing plenary will provide strong input for the Proceedings of this Work Shop and documentation of its contents. Are there any questions on the procedures? Okay. Would the Working Group Chairmen like to add anything to what I have said - Bill, Stan, Dick? Is everyone clear on what their responsibilities are for tomorrow's rather full day? Frank White.

Mr. White - It is not clear to me what the rules of the game are. For example, what constraints must we adopt on our discussion and so forth. I would like more guidance.

Mr. Quinby - I would too Frank, but you ain't going to get it. I have to say that if we tried to agree now on definitions, terms, constraints for discussion we would be inhibiting the product very quickly. This is one of the criticisms which has been leveled at the Lincoln Labs Report. They adopted too much constaint going in. Adopt whatever your Working Group chooses to develop as constraints, and define your own terms. Now if you in a Technical Working Group develop one set of ground rules and the Procedures Working Group develops a conflicting set, fine. We'll

work it out to the best of our ability or recognize the diversity. I don't want to be constrained by that kind of ground rules.

Dr. Koneke - I'd just like to make one comment about constraints, Frank. I had the dubious privilege of helping start with a clean sheet to develop a new Air Traffic Control System and it very quickly turned into an exercise in futility. We were brought back down to earth rather quickly by Neal Blake and by the reminder that we would have to transition to whatever it is that we come up with and we've got a big investment in the system that's out there today. And this thought applies equally to tomorrow's work, and it's important.

CLOSING PLENARY

Mr. Quinby - Good morning, this is the opening of the Closing Plenary Session of the Alternative Separation Concepts Public Work Shop of 1981. The first report this morning will be presented by the Technical Working Group, the second report will be presented by the Procedures Working Group, and the third report will be presented by the Economic Working Group. For the report of the Technical Working Group I'll call on Frank White, as spokesman, and if he doesn't say what you'd like, Mr. Chairman, I'll call upon someone else.

REPORT OF TECHNICAL WORKING GROUP

Mr. White - Good morning, gentlemen. I want to start off by saying I've enjoyed very much being with you and I particularly appreciate and admire our Chairman Stan Halverson who did an outstanding job. He's here on his own time and his own expense which says a lot for the man. Knowing your background, Stan, I'm very humbled by your being here and it was a joy working with you and a great pleasure for me to have the opportunity to present the work of our Technical Working Group.

We started off by selecting an objective.

OBJECTIVE --- To assist in the development of Electronic Flight Rules (EFR) as a suitable alternate, enroute (plus take-off and landing at uncontrolled airports) low altitude (below 18,000 ft. MSL or 10,000 ft. AGL) separation by using available information. To develop a concise statement of a course of action to pursue, with particular emphasis on the technical aspects.

Available information was not intended to mean the information you might have in the airplane, but the available information that was in the room when we started working on the problem. It was available information limited to what we collectively knew. We are to develop a concise statement of a course of action or concept to pursue with particular emphasis on the technical aspects.

CONSTRAINTS --- EFR must:

1. Not require IFR equipped aircraft to add anything to permit EFR to function intermingled with IFR, except Altitude Encoding Transponders.

2. Not decrease IFR safety.

3. Offer perceived benefits to initial installers.

4. Not require exclusive airspace.

5. Require all EFR participants to have Altitude Encoding Transponders.

6. Must be safer than VFR.

Any questions on these constraints? Mr. Krupinski of ALPA has a question on constraint number two.

Mr. Krupinski - Did the group try to discuss or define for themselves what they meant by IFR safety in terms of either Collision Avoidance or separation standards or whatever? What are we really talking about when we say IFR safety?

Mr. White - We asked that question of the expert we have with us Dr. Allen Busch and the figure we've been using is from the discussions in ICAO and in the North Atlantic Systems Planning Group and is at least as safe as less than one collision in ten to the seventh operations or exposures; the probability of unsafe operation is less than one in ten to the seventh. Now if you want to know where that figure came from it's a pure assumption but it's got a lot of background in the work of NAT/SPG in order for them to make their risk model. It's becoming to have quite a bit of acceptance. Ed does that answer your question? Alright sir, any other questions on the constraints?

Okay, candidate solutions.

CANDIDATE SOLUTIONS

1. Enhanced Active BCAS

2. Enhanced Integrated CAS (see Appendix II)

3. Ground-based: Augmented ATARS with Altitude Encoding DABS Transponders.

4. Vertical angle of arrival in aircraft.

5. Automatic Position Announcing System.

6. Full BCAS (augmented).

7. DABS-CAS

Active BCAS. I believe that system is well enough known to you. Recall now that it interrogates both altitude reporting ATCRBS Transponders and DABS Transponders. Remember in DABS now you have the squitter that let's any listening system acquire your address so you automatically can go to the DABS mode and interrogate individual aircraft by their address in the DABS mode. So it has both a DABS and ATCRBS Transponder. That's active BCAS.

ICAS as we know it has been described by Dr. Tom Amlie, it was presented to the New E & D Initiatives Working Group III and there's a good description in those papers and it's a part of their final report. Dr. Amlie also distributed a paper here which will be attached to the Proceedings.

The third candidate solution is a ground-based solution using a DABS Altitude Encoding Transponder. Recall that a DABS Transponder automatically has an ATCRBS Altitude Reporting Transponder and that provides an orderly transition. Yes... It's probably more than "Son of ATARS" Dick Rucker, answering your question. Let's say it this way; ATARS as we understand its design today, is intended to be a Collision Avoidance System. EFR as we understand it today, or my way of describing it, it has to be more range capable and therefore has to come with trying to solve the problem of the two aircraft farther apart and therefore has other problems so it's ATARS plus; it's much more capable than the ATARS.

And the number four candidate solution is the vertical angle of arrival in aircraft. This was looked at in an effort to see if we could beat the problem of having to have an Altitude Reporting capability in the other aircraft in order to have an EFR system work. You know I like to ask stupid questions and I said, gentlemen is there anyone here that can conceive of a system to do the EFR job that does not require the participating aircraft to give the system its altitude. And Dr. Amlie with his normal humor said how about AWACS? And we all had a good chuckle and drove on. And then somebody says why don't we

measure the vertical angle of the signal coming back from a cooperating device. So we looked at that one, and that's what that is; a way to try to beat the need for having the other aircraft give us his altitude.

Number five is an automatic position announcing system. Let's say it's GPS which provides position and you have a data link to announce it, either broadcast or squitter or response to interrogation. We'll get into that more, but that's what we're talking about.

Number six is of course full BCAS and that is about to go into contract.

And finally DABS CAS.

Excuse me, Capt Berube?

Capt. Berube - What happened to Trimodal BCAS?

Mr. White - Trimodal is a much more limited solution than full BCAS. Full BCAS is full compatibility with DABS and therefore would have a long term possibility of survival. Trimodal is not compatible with DABS and was an interim step toward full BCAS which was worked out by the FAA Tiger Team as a DABS compatible longer term solution. Dr. Koenke have I stated that reasonably correct? Alright sir, does that answer your question Capt. Berube?

And finally DABS CAS. This is a more limited set of Active and Full BCAS, using only DABS. In other words this would be sometime in the distant future when you would give up the ATCRBS because nobody had it anymore. And obviously you'd save a significant amount of money because getting the cooperation out of an ATCRBS aircraft where it only has one antenna is a big tough part of the active BCAS problem. So it's a limited set but it's looked at as a long-term solution. Yes, Ed Krupinski again has a question.

Mr. Krupinski - Frank, again let me ask is it supposed to be implied here that any one of these concepts is supposed to be a solution to EFR?

Mr. White - Yes, they are all candidates, and later on we combine them and we'll get into that. But as we look at them at this point of our discussions we considered each one by itself.

Mr. Krupinski - Are we saying that Active BCAS as we know it today could be used for EFR?

Mr. White - Not as we know it today, but suitably beefed up.

Mr. Krupinski - You are implying though Frank, that Active BCAS could do it all by itself.

Mr. White - We will examine the Pro's and Con's of these candidate solutions and I think we'll answer your question. Where we say "solution" here maybe we should say "technology" that might provide a means of EFR.

Alright now we look at them in turn. We start off with the one that's on the top of the list:

ACTIVE BCAS

Pro's: (a) Uses altitude reporting Transponder which is necessary to ATC.

(b) Nearing its production stage.

Con's: (a) Range and reliability may be inadequate for primary separation system (EFR).

(b) Limited to vertical maneuvers.

(c) Limited to traffic densities below .02 acft/NM^2 in ATCRBS mode.

BCAS uses the Altitude Reporting Transponder which is largely in place for ATC. Another Pro is that it is nearing its production stage. The Con's are that its range and reliability may be inadequate for a primary separation system, which is what we call EFR. Guys are out there with EFR passing each other, it's the only means they have of providing separation, so it's a primary means. Active BCAS is limited to vertical maneuvers and limited to traffic density below 0.02 aircraft per square Nautical Mile in the ATCRBS mode. That's because you have an omni directional antenna and you're interrogating everybody. In the DABS mode you do not have that limitation, so we added "in the ATCRBS mode". Are there any questions on Active BCAS? Ed Krupinski again.

Mr. Krupinski - It's not a question really, but I would hope that something at least comes out of this group effort to get some consensus that no type of CAS be it ATARS, Active BCAS, Full BCAS, or Tri-modal as we know those technologies today would be considered as the primary means of separation in the EFR environment. Do we have that kind of consensus or not?

Mr. White - I think, Ed, by the time we get thru the presentation you'll see that we've covered that. Maybe I should cover it in this way: one of the Con's for example is "range and reliability may be inadequate for primary separation system". Now what this says is what Ed Krupinski has already pointed out: the present concept for using Active BCAS as a Collision Avoidance System says that you will have your avoiding maneuvers and your command of maneuvers something like 20-seconds from point of closest approach. And therefore the maximum range you need out of the system even for two aircraft approaching head on at almost MACH I is only 13-Nautical Miles. Now what Ed Krupinski is saying is"Yeah, I don't like that." All we can add to that is Amen, brother.

So what we're saying here is the Con,"Range and reliability, may be inadequate for primary separation system." This says you can't do it with the range and reliability of the existing Active BCAS if you want 99.9% reliability because that's what we have as an objective. The objective of the EFR system you will recall way back,when Gil first put it on paper, was to have a system performance, an operational performance of four nines. Remember Gil's famous paper. Now we know right today that Active BCAS both in the DABS mode and in the ATCRBS mode cannot possibly provide air-to-air surveillance of anything like 99.99. You know we've already identified Lincoln Labs in their extensive work and FAA here at Technical Center in all of their flying of Active BCAS have already clearly identified that no way can you get 99.99with the system as it is today.

Mr. Quinby - A point of procedure I think. Frank is presenting the work of the Technical Working Group as it developed from a broad conceptual objective and statement of what are the things we ought to talk about thru a discussion of the quality of those proposed, possible candidate solutions down to a ranking and prioritizing and defining of where further study and development is recommended. So let's not start questioning the things until he gets down to the pro's and con's ranking of the solutions. Second, let's remember that we're not rigidly bound by any constraints of this meeting or of previous efforts. If we get down to the nut and we find out that this is the best candidate solution but it won't work because back in 1978 we had a constraint that this violates, let's re-examine those constraints, Continually.

Mr. White - Thank you Gil. I believe then we're thru with Active BCAS, let's look at ICAS.

ICAS (Integrated CAS)

(1030/1030 MHz Transmitter Transponder with (1/4 microsecond) short pulses, using ANTC 117 logic added to normal Altitude Reporting ATC Transponder.)

Pro's: (a) Works in all airspace.

(b) Makes use of ATC Transponder RF circuitry.

Con's: (a) Requires new Transponders for IFR fleet.

(b) May lack range and reliability for primary separation system (EFR)

(c) Requires 100% equipage.

(d) Limited to vertical maneuvers.

(e) Requires system testing.

(f) Question of RF interference with ATC Beacon RF.

This is Dr. Amlie's proposal and I believe it's reasonably self-explanatory if you're aware of what Dr. Amlie is proposing. Are there any questions on ICAS? I think the Con's are reasonably complete, we did spend quite a bit of time on this and one of the toughies is the question of RF interference to the ATCRBS Transponder RF. You see the ICAS uses 1030-1030 which is the uplink and if you want to pick a frequency that we get very nervous about it's the uplink frequency, the one that interrogates the Transponders. That's why in the assessment that has been of ICAS up to this point that a number of very tough problems have been pointed out. We discussed in the Working Group the problem of interference on this uplink. Also, it requires 100 percent equipage of participants before one gets full protection. There are some toughies there. But Tom is persistent and a good salesman and so we felt that we ought to at least list it and we did. Any other discussion needed of number two?

Capt. Berube - Since Active BCAS and ICAS were considered as candidates for EFR why was Tri-modal BCAS not considered an alternative and also why was CDTI, however driven, not considered as an alternative?

Mr. White - Thank you Captain. As I indicated previously Tri-modal is a limited substitute for Full BCAS and offers less performance for a shorter period of time. It could have been looked at but I think we would end up in similar capability and similar limitations to Full BCAS. So we looked at Full BCAS as being a more complete and longer term solution. Nobody asked the question. Art McComas has a comment - yes Art?

Mr. McComas - I'd respond to Roy's question with an answer that the Full BCAS was a fully corrected or workable version of what was formerly referred to as a Tri-modal BCAS. We've eliminated all the unworkable parts and substituted workable schemes. That would be my response.

Mr. White - I think that's an excellent addition, Art McComas, to my more limited statement. Captain Berube did you have something to say?

Capt. Berube - Yes. I appreciate having that entered into the record, Art, however there is a curious factor here in that we all would agree that Active BCAS as such would be similarly limited and yet it was listed as a candidate. I think it's important we as a group by some direct or indirect means consider and discount it. How about CDTI, did you consider it?

Mr. White - CDTI is a means of displaying information in the cockpit and we did not look at display as such Captain Berube. Information sources and so on are what we looked at and I guess it's fair to say that we did not look at CDTI as a means of providing EFR without some sensing and computational means. I consider that you're saying, "Can CDTI itself provide EFR"? and we would have come up with conclusions that said, by itself without some input it would not solve the problem. But we did not look at a display as a means. Dr. Koenke has a comment.

Dr. Koenke - Frank, for the record, I would like to know when you were brainstorming these candidates was LCAS or Tri-modal BCAS mentioned, and was a consensus reached for it not to be considered?

Mr. White - Yes.

I believe we're on number three now, ground-based with Altitude Encoder.

GROUND BASED (DABS ALTITUDE ENCODING TRANSPONDER)

Pro's: (a) Centralized coordination and compensation at ARTCC.

(b) IFR intent is known.

(c) Works in high density airspace.

(d) No range limitation.

(e) Horizontal and Vertical avoidance maneuvers.

(f) No unique hardware for IFR (assuming Altitude Reporting is required).

(g) High reliability (99.99% or better).

(h) More flexibility and more opportunities for backup coverage.

(i) Ground system is aware of airborne failures.

Con's: (a) Limited coverage (line-of-sight).

(b) Interaction with IFR system needs investigation (including need for DABS Transponders in all aircraft).

(c) Ground computer failure removes protection.

You will see that this has to be done not at the DABS site but at the ARTCC. We want to have the knowledge of the flight plans so we have more knowledge of intent in the solution. And under (g) High reliability 99.99% or better. The reason we didn't want to stick with the 99.99 is it's the same number that Gil came up with and certainly the total ATC system is 99.99 or better and that's why we added the "or better" so it could accomplish the more limited objective that Gil had for the EFR system. Any questions on the ground-based Pro's and Con's? Later we're going to merge this with another solution as you'll see. Yes, Gil.

Mr. Quinby - In the Con's did you consider the resolution, the angular resolution errors?

Mr. White - We talked about the resolution capability and felt that the EFR concept could accommodate that. It would simply increase the amount of airspace used. But we didn't consider that as a limitation. It could end up being a limitation but as we saw it within the coverage you could make it work. Again you may not be satisfied with how much airspace would be required. We recognized it and discussed it. It probably would have been useful to put some notes down but we considered signal coverage much more important. Any other questions on this one?

Major Popp - Did you consider the fact that it only is good where DABS coverage exists?

Mr. White - Limited to line-of-sight coverage. That's what that means. Oh, you mean where there's only limited line-of-sight from the ground installation. We handle this a little bit later as you'll see. Yes , that's a major limitation. Any other questions on this one?

Okay, vertical angle of arrival Pro's and the Con's.

VERTICAL ANGLE OF ARRIVAL

Pro's:(a) Provides alternative to Altitude Reporting Transponder for air-to-air surveillance.

Con's:(a) Difficult to impossible to obtain required accuracy.

(b) Altitude Encoding will still be required for the aircraft to function in ATC system in much of the airspace.

NOTE: Has advantages and disadvantages of Active BCAS and Full BCAS.

Any questions on this one. I think the Con that beats it pretty badly is that Altitude Encoding will still be required for the aircraft to function in the ATC system, and much of the airspace. So why go to the trouble of a complex alternative to Altitude Reporting when we're going to have Altitude Reporting anyhow. So that one kind of defeats it hands-down.

Mr. White - Okay Automatic Positioning System number five. These are the solutions where you would use a very precise navigation system such as LORAN C or GPS Global Positioning Satellite NAVSTAR and a Data Link such as JTIDS and Altitude Reporting, as a means of position announcing.

AUTOMATIC POSITION ANNOUNCING SYSTEM

(Such as DME/DME, LORAN C, GPS, JTIDS) All use Altitude Reporting (provided by own aircraft).

Pro's:(a) Universal coverage, including low altitude and over ocean.

Con's:(a) All aircraft must be equipped.

(b) Requires complex navigation and Data Link Systems.

(c) A concept only which would require extensive development.

Having accurate position you could make the EFR work. I believe some papers have been written up on this, this is not a new concept. For instance in the E & D Initiatives there is a paper in there that talks about it. Dick Stutz of Sikorsky or Glen Gilbert wrote of using GPS for this purpose. So this is not a new concept. And there are a number of interesting Pro's. I tend to think of it as a longer term solution. Using satellites, obviously gives you lower altitude coverage and therefore it is quite clear why the helicopter operators are very interested in this sort of solution. They are down lower and it is next to impossible to get full coverage on them out of a ground-based system. Excuse me a question. Yes, Captain Berube.

Capt. Berube - Lest there be a question in my mind, the automatic position announcing system seems to be based on something like the GPS. Could it have been driven by let's say a DME DME updated INS position information broadcast? Was that ever considered?

Mr. White - We talked about DME DME but we didn't get very serious about it because it has the limitations, the low altitude limitations, it has to be line-of-sight of at least two DME's and this is a pretty serious limitation.

Capt. Berube - Maybe it should be considered some more by subsequent studies because of the fact that the short term accuracy of the INS is reliable if there has been a DME DME update of a recent time frame.

Mr. White - You're saying, DME DME plus INS, well we honestly did not get into that kind of a system. We did not consider it. Yes Tom,have a question?

Dr. Amlie - Why not use DME DME all by itself as a source for Automatic Position Announcing?

Mr. White - I think that's an excellent comment, let me enter that into the record. Everything available should be considered as a means of getting position. Okay? I think DME DME is an excellent addition. How about the Working Group? Is everybody happy with that? I see a lot of heads nodding. Fine. Of course universal coverage is not provided by the DME DME type of solution, you see the other examples are low frequency or satellite-based systems that provide all altitude coverage.

Capt. Berube - Over which continental mass? My understanding of the development of EFR is for the continental airspace, not for transoceanic operation.

Mr. White - I did not know that for sure. I think EFR is a system that ought to have more applicability than that.

Capt. Berube - I agree. Will all the gentlemen present of the ICAO contingent please raise their hands? There are two points that I'm trying to bring out. The first one is relative to the notion of the DME DME or other updated inertial system providing position output. Number two, it is my understanding that the participation in this meeting limits EFR consideration to the continental mass and that if it is intended as a broader base operation than that then we don't have adequate representation at the meeting to draw conclusions for transoceanic or foreign use.

Mr. White - Yes, Gil Quinby.

Mr. Quinby - We did not limit the technical operation of EFR to the continental mass. If the Procedural Working Group chooses, it has that privilege.

Mr. White - Thank you Gil, that's a better comment than I made and I think it's very helpful at this point.

Now we go to Full BCAS.

FULL BCAS

Pro's: (a) Uses Altitude Reporting Transponder which is necessary to ATC.

(b) Provides both horizontal and vertical avoiding maneuvers.

(c) Works in all airspace.

(d) Reduces interference to ATC beacon system.

Con's: (a) Range and reliability may be inadequate for primary separation system (EFR).

(b) Technically complex.

Any questions or comments?

Mr. Krupinski - "Technically complex" is one of the Con's under Full BCAS in terms of using it as a base for EFR. How is it any more complex than any of the others?

Mr. White - Art would you like to comment please?

Mr. McComas - I think it came about really as a result of strong feelings that it was very costly and since we were not permitted to address the economics issue by the ground rules this is the way that the group felt that they could draw attention to the ultimate cost of it. I don't happen to agree with that myself, but was the feeling of the group.

Mr. White - Okay? Are we up to DABS CAS then.

DABS CAS

(DABS mode only of Active BCAS).

Pro's: (a) Works in all airspace.

(b) Uses same Transponder as DABS in ATC System.

(c) Has been tested and surveillance performance is known.

Pro's: (d) Surveillance communications is addressed.

(e) Also provides horizontal avoiding maneuvers in Full BCAS version.

Con's: (a) Requires Altitude Reporting Transponders in entire fleet.

(b) Limited to vertical maneuvers.

(c) Range and reliability may be inadequate for EFR.

Mr. White - Is there a question or comment?

Mr. Couch - You have listed as a Con under Full BCAS "range and reliability may be inadequate" (Con (a). I see it is not listed under DABS CAS. Does the range and reliability in DABS CAS when we no longer have to deal with ATCRBS, increase to the point where it may be a better candidate for getting the data sonner?

Mr. White - I think this comment applies to DABS CAS then and I believe it's a valid comment and I believe we should add under Con, under DABS CAS "range and reliability may be limited for EFR application". Thank you. Any objection to that by the way? Thank you; good comment. Yes, Captain Berube?

Capt. Berube - Previous solutions have indicated that they may be limited by line-of-sight but DABS CAS does not have that limitation indicated and in fact the reverse is indicated whereby the Pro's indicate that it works in all airspace.

Mr. White - Yes, that is a fact. It does work in all airspace. Because it is not limited by the problem of synchronous garble as the Active BCAS is. And it does not have line-of-sight limitations because it's an air-to-air system. Art do you want to argue with that? Art McComas has a further question or comment.

Mr. McComas - I think the only candidate where it was stated that there was line-of-sight limitation was the ground system, Roy, and that had to do with antenna coverage relative to the earth and that sort of thing. It was not applied to any of the air derived systems.

Mr. White - Exactly. Thank you Art, that was very helpful. Dr. Koenke?

Dr. Koenke - As a point of clarification here I would like to make sure people know that CAS, Active BCAS or Full BCAS, do not rely on the installation of DABS Ground Stations. And while the DABS Ground Station has the line-of-sight limitation, those being airborne systems not relying on Ground DABS do not suffer the same limitation.

Mr. White - However, they may have range limitation, and the EFR concept is carefully defined.

GRADING OF PROSPECTIVE SOLUTIONS

We've gone completely thru the Pro's and Con's on all of the candidates that we identified and now we are going to grade the prospective solutions. We have three grades:

A - Pursue the concept for Electronic Flight Rules,
B - Questionable for Electronic Flight Rules, and
C - Discarded for Electronic Flight Rules.

Active BCAS gets a "B" which is "questionable". Range and reliability for primary separation, that is, Electronic Flight Rules, is questionable. I believe, Ed Krupinski, that speaks to the question you raised earlier.

We grouped together number two, ICAS, number five, Automatic Position Announcing Systems, and number seven, DABS CAS. And we grade them all "C"; discard for Electronic Flight Rules because they violate constraints one and three. Constraint one is, it should not require IFR equipped aircraft to add anything to permit Electronic Flight Rules to function intermingled with IFR except Altitude Reporting Transponders, and constraint three benefits to EFR must be perceived initially. Gil Quinby?

Mr. Quinby - If we're really going to be technically accurate can we say that a DABS CAS in a DABS environment violates constraint three? Because a DABS environment assumes that all Transponders are DABS. And you said here that it violates constraint three.

Mr. White - Gil Quinby's comment applies to the world many years from now when everybody's DABS equipped. That world is so far in the future that we tried to discuss how to handle

that by merging the DABS ground environment with an airborne environment which we'll get to in a minute. But the world which we're talking about when everybody is DABS equipped is a far-future world we really didn't deal with. We looked at a world that includes the transition to DABS, and therefore to DABS CAS.

Ground-based candidate solution number three: Augmented ATARS with DABS Altitude Encoding Transponder is graded a conconditional "A", in other words conditionally pursue the concept because if it works within DABS surveillance it should be pursued as a candidate. But it may increase the controller workload by requiring controller intervention until all IFR aircraft all have the DABS uplink. We later combined number three and seven and we'll get to that later. Three is not complete by itself. But it deals with earlier questions, with regard to line-of-sight coverage, and "how does it work when we don't have DABS surveillance", and so on.

Vertical angle of arrival at an aircraft, we gave it a grade "C" due to the question of technical feasibility.

Full BCAS we graded "B". It's a little better than Active BCAS, but we didn't have B+ or B- so we said range and reliability for primary separation is questionable. It is going to be more costly than Active BCAS, however, it provides a more complete solution. Alright any questions so far?

Now we get down to the final which is a combination of Candidate Solutions Number Three and Seven (DABS CAS used to compliment ground-based DABS surveillance system). Grade "A". Where DABS ground surveillance, candidate solution number three, has not been provided (or in areas where it may never be provided) add airborne DABS CAS suitably modified for EFR application. This is seen as a long-term solution, at least ten years hence. In the meantime, Active BCAS or Full BCAS suitably modified for EFR can be used by those aircraft which desire to use them.

Any other comments, questions?

Mr. Couch - I want to get the consensus of the group here, back when we were discussing number three, Item (a) centralized coordination and computation at ARTCC. We have now come to the group's conclusion that if we could have it, the ground-based DABS would be one of the best ways we could get the information up there. Do we conclude from this the advisibility of

having the ground-based data bank which contains adequate positional information and/or intent might be better if EFR operations filed a flight plan. Do we need that sort of information to do the best job of providing to the aircraft the type of data for use in the EFR separation?

Mr. White - My understanding is the answer is yes, flight plan data would be useful also so we know the intent of the EFR aircraft. It's better than not having the information. I believe it will be helpful.

REMAINING PROBLEMS

In the recommendation of number three complemented by number seven a lot of unanswered questions or problems exist. The following are among the most obvious:

1. PROBLEM: Within DABS/ATARS/EFR ground surveillance a DABS Transponder equipped aircraft using EFR separation (no Flight Plan to ATC) begins to converge with an IFR (ATC participation) aircraft which is Altitude Reporting ATCRBS equipped but not DABS equipped. The ground DABS/ATARS/EFR system attempts to automatically provide safe (EFR) passage for the EFR and IFR aircraft. If, for some reason, (e.g. more capability, speed, maneuverability, etc.) the IFR aircraft bears down on the EFR aircraft, safety becomes marginal as perceived by the automatic ground system. The automatic system alerts the controller to take action. What is the rate of such problems, what controller participation may be necessary and what sorts of solutions are used by the controller?

Mr. White continued... Alright have you the problem in your mind? Ground DABS/ATARS/EFR system attempts to automatically provide safe EFR passage for the EFR and IFR aircraft. Obviously the only one to communicate with automatically is the EFR equipped aircraft so it tries to resolve the problem by keeping the EFR equipped aircraft out of the way of the IFR aircraft. If for some reason; for example, more capability, speed and so on, the IFR aircraft bears down on the EFR aircraft, safety becomes marginal as perceived by the automatic ground system. The automatic system alerts the controller to take action.

Mr. White - Mr. Couch does this speak to your question? Ed Krupinski has a question or comment.

Mr. Krupinski - Will somebooy tell me how the system will automatically alert the controller that he must take action?

Mr. White - By the altitude you put into the EFR addition to the ground-based computer. Just like it does now with conflict alert. The pair of aircraft are getting too close as perceived by the ground environment.

Mr. Krupinski - Well all of the discussions in the Procedures Group, I think, worked on the assumption that the EFR pilot was assuming the responsibility for separation.

Mr. White - That is not correct. There is no way the EFR pilot can assume the responsibility, all he does is what the EFR system tells him to do. Am I wrong? Straighten me out.

Mr. Krupinski - No Frank, I know you're not wrong. I may be, but not you. I wish we'd have know that in the group we were working in because I think we'd have viewed the whole thing a lot differently. I think that's pretty much of an unacceptable situation to the controller to speak for them.

Mr. Quinby - Real quick here. An observation: This is not unexpected at all. If this turns out to be the only place where the two major working groups came up with different approaches to the definition of EFR I'm as happy as I can be. There will be more and this is healthy.

Mr. Krupinski - Most of us participated in the Group III discussions originally on this whole thing, and I don't think there ever was at that time and even as of yesterday I thought that there was not a clear consensus of understanding of what the objectives of an EFR concept were. I've tried to get a definition of that in our own group and we didn't come up with it. I still feel that the concept means one thing to one person and something else to another. Unless we all get the clear understanding and agreement on the concept we're going to have these differences and we're just not going to solve the objectives of EFR.

Mr.Quinby - I agree wholeheartedly. But my hope is that after we get the reports of this Work Shop into the record that we will know more about the concepts of EFR than we did at the beginning of the week.

Prof. Hollister - There is not as much discrepancy as you're trying to make out of this because a resolution command that goes to the controller may only be to keep the IFR aircraft on an IFR Flight Plan which he's already on and just making certain that the controller doesn't give him a sudden vector to offset the computed solution by the EFR system. And you could still have the EFR aircraft being the aircraft that avoids. All you're doing is just trying to alert the controller that that's the action being taken by the EFR aircraft. And I don't think that that makes such a big difference between the assumptions that your group made and the assumptions that this group made.

Mr. White - That's precisely the way I feel in my own mind. And I think that one will work out. But certainly it's a problem that has to be put into simulation and be looked at.

Mr. Rucker - Just a comment, I think that in our Working Group we spent more time on how do we get information on the aircraft in the first place.

Mr. White - On the EFR aircraft?

Mr. Rucker - All I'm pointing out is - given I have a neighbor that I am in conflict with we never really addressed the question - is the resolution something conceived in the mind of the pilot or something computed and given as a solution to the pilot or something in between. I think that's what the issue is. I heard the good Doctor use the word algorithm: the EFR algorithm simply hands the solution; or the resolution, to the pilot. We never used that approach. The closest we got to it was when we were talking about a departure from an uncontrolled airport in IMC conditions and the pilot on the ground, this is Bob Warner ready to take off, and Bob Warner is trying to decide whether he can beat that guy on three mile final or not. We said well maybe it shouldn't be Bob Warner's judgment it should be a box that says, that guy is measured within three miles so don't go.

Mr. White - That happens to be problem number two. Thank you for the introduction.

2. PROBLEM: An EFR equipped aircraft desires to leave an airport having no Control Tower. It is assumed that if the airport had a tower, the pilot would contact the tower, obtain a takeoff clearance, and be handled until the aircraft was at or near its cruising altitude or at least outside of the control area at which point the flight would be

released to EFR. How can the EFR system function properly without own aircraft velocity vectors which cannot be input to the EFR system until the aircraft is airborne and its accelerations are reasonably minimum? Is one possible solution the use of a "range lockout"? That is, measure the range to nearest aircraft and prevent the EFR equipped aircraft to take off until the Tau declares it is safe. Tau could have as an input a "worst case" assumed velocity vector for"own"aircraft. One possibility is for EFR equipped aircraft to position itself on the take off runway and have the EFR system look in the direction of departure using its directional antenna. How good would such relative bearing data have to be for proper operation to result (not necessarily including the ability to provide horizontal escape maneuvers)?

Mr. White - Okay any questions or comments on this one? Okay Bob Warner is going to comment on this one or ask a question.

Mr. Warner - My only comment with a directional antenna is that when you depart IFR from that airport in many cases you have to go in the other direction. You are taking off in one direction but the only way out with the terrain or NAV aid is the opposite. So if the directional antenna is all you have available then you would have to do a turn around or something to look in all directions.

Mr. White - The antenna does the searching. It's part of the problem set. As Gil says, "we're putting down problems not answers". I guess I went too far in suggesting the scope of the directional capability. Yes, it's a possibility; part of the sub-set.

3. PROBLEM : Effectiveness of DABS CAS or Active BCAS, or Full BCAS as a compliment to ground DABS surveillance. The New Initiatives Task Force was seeking operational reliability of 99.99%, this means an air-to-air surveillance reliability higher than 99.99%. The Task Force did not have a short distance range limited system in mind. In other words, warning times larger than about 20-seconds (used by the Active BCAS) were viewed as being necessary. If warning times in the order of a minute or more are desired, it is evident that the ATCRBS Transponder or even the new DABS Transponder will be range limited. How do we solve the problem?

4. PROBLEM: Logic for an EFR system. This logic may be patterned after Active BCAS logic, but a different set of requirements must be developed and a new solution provided.

In other words, we're clearly recognizing that it's based on Active BCAS or Full BCAS but with an entirely different set of operational problems and solutions.

5. PROBLEM: Transition from EFR to IFR at a towered airport in IMC or at a TCA. How does an EFR aircraft obtain entry at his destination in the face of Positive Control or slot problems.

6. PROBLEM: Can an EFR equipped aircraft operate through TCA airspace? With no clearance.

Art McComas has a question or comment.

Mr.McComas - For anybody that might be interested I tried to take all the restraints that were listed in today's handout against the seven candidate systems and make up a matrix for my own edification. You may find it useful.

Mr. White - Very good. Art has thoughtfully done all this so we each don't have to do it. So here is a handy-dandy matrix, compliments of Art McComas. Thank you Mr. Chairman.

Mr. Quinby - Thank you Frank.

EVALUATION MATRIX

KEY: + = Pro
- = Con

No.	FACTORS	CANDIDATE CONCEPTS: Active BCAS 1	ICAS 2	Gnd. Based 3	Vert. Angle 4	Auto. Pos. Rep. 5	Full BCAS 6	DABS CAS 7
1	Uses Altitude Reporting Xpdr.	+					+	
2	Near Production Stage	+						
3	Questionable Range & Reliability	-	-				-	
4	Limited to Vertical Maneuvers	-	-					-
5	Limited to 0.02 Density	-						
6	Works in all airspace		+	+		+	+	+
7	Common RF Circuitry		+					
8	Requires new IFR Transponders		-					
9	Requires 100% equipage		-			+		
10	Requires System Testing		-					
11	RF Beacon Interference Question		-					
12	Centralized Coordination			+				
13	IFR Intent Known			+				
14	No Range Limitation			+				
15	Horizontal and Vertical Maneuvers			+			+	
16	No Unique IFR Hardware			+				
17	High Reliability			+				
18	High Flexibility for Backup			+				
19	Ground System Aware of Failures			+				
20	Limited to Line-of-Sight Coverage			-				
21	Interaction with IFR Question			-				
22	Ground Computer Failure Removes Protection			-				
23	Difficult/Impossible to get accuracy				-			
24	Altitude Report Xponder Required for ATC				-			
25	Requires Complex NAV & Data Link Sys.					-		
26	Concept only/development required					-		
27	Reduces Beacon Interference						+	
28	Technically Complex						-	
29	Uses Same Transponder as DABS							+

No.	FACTORS	Active BCAS 1	ICAS 2	Gnd. Based 3	Vert. Angle 4	Auto. Pos. Rep. 5	Full BCAS 6	DABS CAS 7
		CANDIDATE CONCEPTS						
30	Tested/Performance Known							+
31	Surveillance Communications Addressed							+
32	Horizontal Maneuvers (in Full BCAS version)							+
33	Requires Altitude Reporting Xponders in participating fleet							-

KEY: + = Pro
- = Con

REPORT OF PROCEDURES WORKING GROUP

Mr. Quinby - The Procedures Working Group chaired by Bill Flener will be reported by Bill Flener. We have no script to follow so the report should proceed much more quickly.

Mr. Flener - I would like to thank the Working Group. There was complete consensus in our Working Group. Everybody agreed, all the time, to disagree - we worked the problem. We had one ball that we kept bouncing all the time, and that was to keep in mind that the name of this game was to give Seig Poritzky, Dr. Koenke and Staff ideas; to give them something to work with. As I see it Gil, some type of Working Group like this that has the brains meets again after the FAA overhauls this whole thing.

You've got to look at one of the problems here. IMC or VMC has a long, long history. It goes way back to the thirties. And what we're doing here is we're taking a completely different concept or different idea totally. Most of us won't even see it. We'll be gone by the time it occurs or comes about. We'll be retired, we won't be here to handle this problem because it's going to have a long history and this is a good beginning and I think it's very fine.

I've got three different sets of opinions, and I would like to read thru them rapidly and accept comments or questions or whatever you have at any point.

First, the objective of this particular Working Group was:

-- Make recommendations and suggest policy and procedures regarding the implementation and use of EFR in the National Airspace System. Our primary concern is operational utility rather than technical feasibility.

No prior constraints such as technical suitability of different hardware systems or sacred separation standards were imposed. Neither was system economics considered, although we discussed all of these points. For the purposes of this discussion, it was assumed that the avionics industry can produce and the users can afford equipment which will provide the capabilities discussed herein.

We attempt to postulate EFR characteristics and features that should enhance safety and provide for more time efficient and less costly flight. What I'm reading from at the moment is the basic consensus and although there was agreement and disagreement, this is basically what we came up with. And I'll touch on something that Captain Berube came up with and something that Dick Rucker came up with in a little while. It was agreed that EFR has a definite place in the ATC hierarchy.

EFR as presently defined is superior to VFR but not quite IFR. It should not be considered as a repl cement for either. Specifically we recommend that the FAA pursue development of EFR and the technical systems which make it possible. We define EFR as a system of rules and procedures, different from IFR, which permits flight of a suitably equipped aircraft by a properly certificated pilot in VFR airspace, under IMC, subject to procedural restrictions.

EFR Procedural Recommendations:

1. Part 91 should be amended by including a new paragraph stipulating the equipment requirements for EFR flight. Now we speak here only to Part 91, actually,and as I spoke earlier on history, there has to be a complete review of the Federal Aviation Regulations, the FAR's, of which the users will have their input and that will have to be published in order to accomplish this.

2. It should be clear to EFR pilots that three types of airspace, impose a mandatory ATC communications requirement; Terminal Control Areas, Airport Traffic Areas, and the Positive Control Area. Flight under EFR will not change these existing Communications requirements.

3. Some instrument approaches - including non-precision approaches - penetrate areas of mandatory communications, as I stated above, these approaches should be available to aircraft operating IFR but not to those operating EFR. We had a lot of discussion of this matter. It applies to both precision and non-precision approaches.

4. There should be such a thing as "EFR Advisories" from ATC. This could help avoid the pop-up situation since inbound EFR pilots could begin working with the Center prior to contacting Approach Control, thus perhaps smoothing the transition to a full IFR operation.

5. EFR flights, other than helicopters, should comply with the same MOCA's as ordinary IFR. Where no MOCA is established, the same criteria as used for establishing the MOCA should apply.

6. A Flight Plan should normally not be required for EFR, however, pilots should be encouraged to file EFR for potential search and rescue purposes. File Flight Plans, yes, but you don't have to file a Flight Plan, just as it is today.

7. EFR flight should be permitted only at VFR altitudes (hemispheric rule). Some discussion occurred on this subject - should we go hemispheric rules or should we block altitudes. From an ATC viewpoint I objected to the blocking of altitudes and would prefer the hemispheric rule. Then we got into a big discussion of VMC and IMC. We had a discussion, we didn't quite have a concurrence on that. So EFR flight should be permitted at only VFR altitudes. This would help from the controller's point of view since IFR aircraft in IMC would probably not appreciate being advised of traffic at the same altitude, opposite direction.

EFR Pilot Proficiency Recommendations

1. There should not be a separate EFR rating. This is essentially IFR flight without the communications requirement, but all the other skill and knowledge requirements: instrument theory, weather theory, navigation

and control by reference to instruments, etc. are essentially identical. It would seem reasonable and economical to simply require pilots operating EFR to hold an instrument rating and meet the same recency of experience requirements.

2. Existing instrument rated pilots should meet some additional requirements before certification to EFR. This could be fairly simple - either pass a written test or at the discretion of the individual concerned, take an approved transition course. Once this requirement is met, no further action would be required to fly EFR. Precedents for the less formal testing requirements already exist in such matters as checkouts in complex single engine aircraft.

3. Instruction in flight under EFR should be given by qualified Flight Instructors, Instrument Instructors who have also been trained and rated to instruct IFR, and

4. There should be no distinction between IFR and EFR as far as the certification of Part 135 operators is concerned except that additional EFR training and rating is required.

Now that pretty well sums up what we discussed in our one day that we had and an hour this morning. In addition, Captain Berube came up with some notes last night and I would like to touch upon those:

- His definition of EFR quotes the concensus exactly the same and adds a dissenter; R.A. Berube - He didn't agree.

- EFR is not just CAS. And we've tried to steer clear of getting into CAS problems, or BCAS problems.

- There shall be no exclusive EFR airspace per se.

- Regulations as appropriate shall be modified to permit EFR operations as defined.

- There shall be EFR recurrent training requirements - the every two years requirement - biennial flight review.

- EFR operations are expected to increase safety, ATC capacity, efficiency and reduce total system operational costs per unit in the system. (There was not a consensus on that one).

- Users will equip if they perceive a benefit to their operations in the form of increased flexibility, efficiency or reduced cost. A true statement.

- Implementation must be evolutionary. We had a long discussion, evolutionary versus revolutionary, and the Air Force Officer made a point of evolutionary and it was very well put, I thought, because history indicates that everything else has been that way.

- Benefits must accrue to EFR equipped operators and I'll add parenthetically (or they won't buy).

- EFR must be compatible with ATCRBS, BCAS or DABS --- Full or Active. The history of the Agency's efforts and the efforts of various people in this group have been that equipment that comes on line is compatible with other equipment.

- EFR should operate independent of ATC in VFR Airspace. True.

- Statements of intent broadcast prior to initiations are desirable. That one's true. We had a lot of discussion about that.

- Displays designed must be located in the pilot's "prime viewing area". The point is well taken. Anything that he can view without turning his head and reaching down.

- Failures of EFR must be ennunciated on the pilot panel. In other words,a red light or something should come on.

- Air-to-air and air-to-ground data links are desirable. We were getting into the work of Stan's Group, but we thought we ought to say that.

- An EFR pilot proficiency check is required. Okay,I spoke of that before.

But there are a number of items, actually eleven or nine which were items not completed to consensus and I'll touch on several of these. CDTI type display for EFR. Should we really do that or not do that. Berube would like to do that. ALPA has spoken. I asked Bob Warner, in response to the first question are you speaking for yourself as a pilot,or for AOPA? He thought on it and finds it is AOPA. That's okay.

And there were a number of pilot workload acceptability, controller workload acceptability, statement of intent requirements, total 5D route definition. Captain Berube went into 4D, 5D, R-NAV, SIDS and STARS - some areas that we really didn't get to discuss too much.

The airspace user representatives in the Working Group were tasked with declaring their expectations for an Electronic Flight Rules System, and I found them most revealing. Here they are:

Bob Warner (AOPA)

1. Reduce departure delays in IMC conditions which are due to current procedural separation rules or navigation limitations. For example, IFR departure procedures from uncontrolled airports with instrument approaches.

2. My own guaranteed VFR Traffic Advisory Service everywhere, in both IMC and VMC.

Dick Stutz (Sikorsky)

1. Helicopter operations in both IMC and VMC in all airspace, controlled and uncontrolled. Low density traffic is assumed where EFR alone is used.

2. Increase the capacity of the IFR system.

Lt. Col. Feibelman (Military Air Traffic Controller)

1. As a first step, relaxation of the current rules for VFR and Special VFR flight (reduction of visibility and distance from clouds rules) through the use of electronic augmentation of the human eyeball. For example, increasing the range at which traffic can be acquired for visual avoidance in marginal visibility conditions.

2. Based on the experiences and lessons learned with this first step, explore the potentials of the chosen technology in successive steps. These successive steps would require less and less dependence on either visual acquisition of traffic out the window and/or prior coordination with the Air Traffic Controller.

Roy Berube (Airline Pilot)

1. Collision avoidance backup to the IFR System.

2. Cockpit-based alternatives to some services of the current IFR System, including Bill Cotton's CDTI concept and 5-dimensional R-NAV (3D and speed control and time based ATC).

3. Reduce the dependence of company operations upon the good behavior of a unionized controller work force.

Paul Droulihet (GA Pilot, Lincoln Labs)

1. The ability to fly enroute without contacting the ATC System outside airport or controlled terminal areas.

2. Augment the capacity of the IFR System in a more cost-effective way.

Ed Krupinski (ALPA)

1. Maintain current level of savety of the present system or even improve it. Pilot must have capability of separating own aircraft from other aircraft in much the same manner that the controller can. Requires separate and adequately effective method for primary separation. Use of CAS logic and ranges for primary separation system is unacceptable. Believe concept will require ground-based surveillance where a mix of IFR and EFR is envisioned.

Mr. Flener - I very much appreciate the input of Captain Berube and Mr. Krupinski and everybody else who was involved. I did say, and I'll say it again, keep your eye on that little ball that we're trying to put together and which Gil will try to do off the record and off these papers. Give the FAA something to thing about, that's why we've gotten all these people together.

Mr. Quinby - Thank you very much Bill, and thank you members of the Working Group. I spent relatively little time with you and be advised that I am pleasantly surprise.

REPORT OF ECONOMICS WORKING GROUP

Mr. Quinby - The final group report is from the most exclusive of the Working Groups in fact it got kind of lonesome in that Conference Room. Dick Jensen of the Ohio State University, however, comes out one up because he has visuals for his report. Dick.

Dr. Jensen - I'm sure that it was because of the tremendous interest in the other two groups that we had less members in our group. Nevertheless, I think it's important that we footnote the reports of the whole Work Shop.

Two basic issues were examined. One, to define as best we can the benefits which can accrue to those using EFR. Second, to try to identify the cost to both the user and the government for implementation of EFR.

Actually without having the results of the other two groups available to us there was not much we could do in defining the costs. First of all let's look at statistics that we were able to derive in the area of user population for EFR. And remember the criteria established, we heard from the Technical Group that said that the area of EFR coverage would be below 18,000 ft. for airplanes of less than 250 knots.

I want to express my appreciation for Professor Kennedy of MIT for the work that he has done prior to this meeting in establishing the benefits of EFR. This is one of the tables that he has come up with.

TABLE 1. IFR AIRCRAFT HANDLED BY ARTCC'S (Millions)
(Ref. 1978 FAA Forecast for 1979-90)

FY	Air Carrier	Military	Air Taxi/ Commuter	General Aviation	Percent GA/AT/Commuter
1973	12.6	4.7	0.9	4.6	24%
1974	12.4	4.3	1.1	5.1	27%
1975	12.4	4.4	1.3	5.5	29%
1976	12.4	4.2	1.4	6.0	31%
1977	13.0	4.5	1.6	6.9	33%
1979(f)	14.1	4.4	2.3	8.9	38%
1984(f)	15.4	4.4	4.1	13.0	46%
1989(f)	17.1	4.4	5.6	17.1	51%

NOTE: (f) Denotes Forecast

What it shows is a 1978 FAA Forecast of Aircraft handles between 1973 and 1990. It includes past performances as well as projections into the future (perhaps somewhat optimistic). We might as a first cut divide off the Air Taxi, Commuter and General Aviation as those aircraft that would benefit most from using the EFR concept. You can see from the beginning around 24% in 1973 are of that category up to around 38% at present, and projecting into the future where greater numbers of Air Taxi and business operations are forecasted as high as 50% of all operations would be potential users of the EFR concept. Obviously these statistics are not defined as we would like because General Aviation includes a lot of airplanes that are not flying below 18,000 ft. and less than 250 knots. But as a first cut this is one way of looking at those particulars.

Another way or perhaps a different summary is shown on the next chart, Table 2.

TABLE 2. SINGLE AND MULTI-ENGINE PISTON AIRCRAFT FLYING ACTIVE IFR 1978

Number of Aircraft	66,855
Number with Transponders	64,820
Number with Encoders	32,000
Peak Day IFR Flights	14,339(or 35% of total)

This table presents to us the single and multi-engine poston aircraft which are flying actively in IFR flights in 1978. It's a couple of years old, but these statistics do fairly accurately represent aircraft flying below 18,000 ft. and under 250 knots. Now the number of such aircraft in 1978 is almost 67,000. Of this total 64,800 are equipped with Transponders already. And of this total, we found that those with Transponders, approximately half of those equipped with Transponders have Encoders installed. That was in 1978. And today that statistic would be somewhat higher. People have equipped themselves with Encoders even without the incentive of EFR. There are enough other incentives out there for equipping with Encoders. And so I don't see that that is going to be a big drawback to EFR.

Now the final statistic on Table 2 shows peak day IFR flights. The number shown there for peak day IFR flights is single and multi-engine piston aircraft below 12,500 lbs. That's the best I could come up with for aircraft operating under 18,000 ft. at less than 250 knots. And peak day statistics (for 1977 in this case) shows that 14,339 operations were IFR enroute

operations conducted by aircraft in this category which represented 35% of the total operations on those peak days as counted by the FAA. This seems to represent a significant number of airplanes that could benefit from having EFR. The main thing here is that at least in the enroute environment EFR can reduce controller workload; perhaps not by that amount, but at least reduce the controller workload if many of these aircraft actually flew under EFR as opposed to IFR conditions.

TABLE 3. BENEFITS NEEDING QUANTIFICATION

1. Reduces departure delays - fuel saving
   a. Tower controlled
   b. Non-tower controlled
2. Slow demand increase for ATC service
3. Freedom to fly in IMC as in VMC - fuel saving
   a. Cancel IFR for EFR
   b. Flexible routes
   c. No required flight plan
4. Finally makes RNAV achievable without denial by ATC - fuel saving
5. Could eliminate the need for controller-initiated traffic advisories

Table 3 has to do with benefits and in most cases we see the benefits needing quantification because we don't have firm data yet. Most of these were talked about in the other groups and that's the reason for our being here I suppose. As we have been suggesting on our first two Tables, EFR can slow the increase in demand for ATC service by offering an alternative to aircraft wanting IFR flights. The freedom to fly in IMC conditions as in VMC conditions and the ability to cancel IFR and go EFR if you don't like what the controller gave you for clearance can be tempting benefits. Also, the flexibility of pilot-preferred routing and a lack of a requirement for a Flight Plan as well.

I did a lot of research on AREA NAV and have been frustrated with controllers who haven't been willing to give RNAV routes for many flights and I think EFR can help cure this. We need the capability for going RNAV in many areas where it might not be practical to go IFR. And finally one of the benefits we identified is to eliminate the need for controller indicated traffic advisories which would reduce their workload.

The next Table has to do with the costs.

TABLE 4: COSTS OF EFR

TO USERS

1.	Transponders for a few aircraft	2,000
2.	Encoders for approximately half of the active IFR aircraft	32,000
3.	Primary separation black box for those among the 67,000	
4.	Some training cost	

TO GOVERNMENT

1. Extensive R & D effort to prove safety of EFR and develop procedures
2. Purchase and installation of new ground systems
3. *Purchase of extensive software* for new computers

First of all users, from our statistics, the aircraft actively flying IFR that still lack Transponders are very few. Some 2,000 aircraft mostly light single-engined, fly IFR and would need to add Transponders. Perhaps as many as 32,000 will need to add Encoders, to go into this environment. And as many of the 67,000 who currently fly IFR and wish to add EFR capability will need to add the black box or whatever it takes to do the EFR operation. And finally, the cost for the user is the training cost which was mentioned by the previous group fairly extensively.

As for government we didn't have such clear ideas on things the government would have to pay for here, but obviously there will be an extensive R & D Program to prove the safety of EFR and develop the procedures. And secondly, to purchase and install our ground systems - surveillance systems or whatever the systems are that are needed to handle EFR and finally the purchase of appropriate software for the new computers.

This as I said, is restricted to pilots who fly under 18,000 ft., 250 knots or less. We think that's what we see today but perhaps in the future it will be a concept that will go beyond this limitation. Perhaps the Airlines and other users of that level will also participate once they can see some benefits. That's the report of the Economics Group.

Dr. Koenke - Could you tell me in the statistics that you cited, has the effect of deregulation been included in those statistics, the projections you know up until 1990?

Dr. Jensen - I'm going to ask Bob to comment on that.

Mr. Kennedy - The FAA Forecasts include that. Yes they have. It is not based on the most current forecast. The forecast goes to about 1989. I have been doing this sort of thing to clear my own thoughts on the matter. To some degree it does include them but I haven't incorporated the most recent forecast.

Dr. Koenke - So this then was the 1979 Forecast and does not reflect the most recent work done in the 1981-82 time frame?

Mr. Kennedy - That's correct.

Dr. Koenke - Thank you very much.

(Unidentified Questioner) - My question has to do with the cost of equipment inhibiting the growth of EFR both to the people who wish to participate in EFR as well as those who would be required to add equipment to make EFR or IFR possible for others.

Dr. Jensen - We discussed that to some extent and were surprised by looking at the statistics how many had equipped themselves with Transponders and Encoders without the EFR incentive. Even Bob Warner agrees that by the time EFR comes into existence we very well might not have a problem at all. We might already have added this capability.

(Unidentified Questioner) - I don't know whether this is a comment or a question or if it's even yours, but I wonder who would like to participate in this program say if EFR progresses as we would all like to see it progress. If anyone took a look at those who want to participate and may not have the physical space in their aircraft to even install a black box or any type of a display.

Dr. Koenke - That's a good point. The Equipment and Technology Group at least as far as I understood, talked about the equipment requirement being a DABS type of CAS or an Active BCAS or something like that enhanced to be able to handle EFR. Now maybe the DABS/CAS concept integrated the Collision Avoidance System with the Transponder so you would have a unit there which would be packaged to include both elements. Now if there isn't sufficient space for the box or for the display on the panel, maybe there's a problem.

Mr. Hollister - Since the Pandora's Box has been opened Military thinking has gone so far as to consider new systems like JTIDS. You might not want to include a DABS in the system, but instead put a JTIDS terminal at the center and pass all the information that the center had to have on the Military Aircraft thru the JTIDS link. And that would be a serious problem if you were going to try to do EFR with Military Aircraft in the airspace. With regard to the Military it's more than just a question of there being room for the box. It's what will be the Military participation. They've got 20,000 airplanes out there not counting helicopters I guess, and it's a very good question as to how the Military will interact.

Mr. Quinby - It would be nice if we could go further into this. I think, however, that the product of this Working Group as a group consensus is limited and is in the record as of about now. I recommend that individual opinions that have not been adequately covered in the group's expression which you have heard today be drafted for supplemental transmission to the Office of System Engineering Management if the Proceedings of this Work Shop are not, in the opinion of any member of the Work Shop, adequate.

The group has supported EFR. It definitely encourages further exploration and development, and it has offered some areas in which the FAA should proceed. Now the Proceedings, as this Closing Plenary has done, will report this, faithfully and completely. If there are those here with strong feelings that are not adequately represented by the Proceedings' effort to report the consensus, please feel free to supplement the Proceedings with further input to FAA.

Dr. Koenke - I would like to remind the group that Bill Flener made a recommendation that at the time that the recommendations that you all have made are strengthened by further study we should get this group back together. I agree with that. We do not intend just to put the results of this Work Shop on the back burner. We do intend to take a very hard look at the recommendations that the Work Shop is going to make formally. Also, we do have a process that we use faithfully where we go out to Air Traffic, Airways Facilities, ATA, AOPA, ALPA, GAMA and all the rest of them and ask them what priorities we should give all of these programs when we look at them in context with each other. And we try to weigh all these recommendations and come up with a priority list.

So what I can say is that at such time as is appropriate and when we have something more definitive we should all get back together and look at EFR in relation to programs which are presently much further along.

Mr. Quinby - The sense of enthusiasm for the EFR concept has been reinforced at this Work Shop. I think that the Proceedings will accomplish the purpose that was hoped for by the organizer and by OSEM in giving them better handles to grab the concept by then existed before. FAA was just out of ways to spend money or put people to work on EFR. Now they have some such directions, one of which is that maybe we will get into periodic Work Shop updates of the concept. Hopefully in some reasonably predictable future, EFR will be as well defined and developed, as some other programs now in the process of development - ATARS, AERA, and so on. We're not there yet with EFR. Alright? Are there any other additional comments before we wind down this Work Shop? Dr. Koenke.

Dr. Koenke - I would like to express my thanks to Gil and congratulate Gil on a job well done in spite of a lot of odds. And to thank all of you because this couldn't have happened without all of you. Personally, I feel very satisfied with the results because I can see things much more clearly and put them in context with the rest of the work that's going on. I think the results of this Work Shop are extremely successful; I think they are going to help us very much, and I think that we will be moving out on EFR. Again thank you all for your help and for the time you've put in and we'll be back together I'm sure. Thank you very, very much.

Mr. Quinby - I'm sorry we ran overtime. We're forty-two minutes late adjourning in accordance with the Agenda.

(Unidentified Questioner) - Whom should we address letters to with comment on the Proceedings?

Mr. Quinby - Letters should be addressed to the Office of System Engineering Management at FAA in Washington, D.C. and refer to this work shop. I work for them, and if you want to copy me, that's fine.

I can't thank you all enough for coming here and working as hard as you did to do this job. It takes a team of this capability to push this kind of concept further along in the job of definition. It won't go away. Maybe its viability was suspect by some before this Work Shop, but it can no longer be suspect in my opinion. It will live and it will grow, and someday in some form it will see the light of day in operational use of hardware and procedures. We will be calling on you. I don't know when or how, but this talent will be reassembled sometime when there is progress to monitor.

So I thank you all for your help this week, and expect your help when next you receive a call. I trust you will be satisfied with the Proceedings. If not, remember what I said in opening this thing. I'm the Coordinator, that means if there's anything wrong, it's my fault. Get in touch. This Work Shop is adjourned.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

This final chapter is a synthesis by the Work Shop Coordinator of the essential products of the Alternative Separation Concepts Public Work Shop. It does not substitute for or take any precedence over the Public Record which is documented in the preceding chapters.

SECTION I - TECHNICAL WORKING GROUP

OBJECTIVE - To assist in the development of Electronic Flight Rules as a suitable alternate enroute (plus takeoff and landing at uncontrolled airports), low altitude (below 18,000 ft. MSL or 10,000 ft. AGL), separation (system) using knowledge and information available to us at this meeting. To develop a concise statement of a course of action to pursue with particular emphasis on the technical aspects.

In the Technical Working Group with the expertise assembled it was constantly necessary to remember that we were using a kind of shorthand in our discussions. When we said, "BCAS" for instance we were not talking about the hardware which is being developed and the technical standards that are being drafted for one or another of the Beacon-based Collision Avoidance Systems today. We were talking about an extension of that kind of technology rather than that particular collection of hardware. The need to distinguish between the mission of Collision Avoidance, or last ditch crisis avoidance and separation assurance as a primary separation system was of vital importance to our discussions. Collision Avoidance devices are backups to a primary separation system. A primary separation system should be capable of independently substituting for one of the existing primary systems.

Certain constraints were adopted by the Technical Working Group for purpose of aiding discussion at this Work Shop. They were:

1. EFR must not require IFR equipped aircraft to add any special equipment to permit EFR to function in co-existence with IFR operations. Altitude Encoding Transponders are not considered special equipment for this paragraph.

2. EFR must not decrease IFR safety.

3. EFR must offer perceived benefits to initial installers.

4. EFR must not require exclusive airspace.

5. EFR must require all EFR participants to have Altitude Encoding Transponders.

6. EFR must be safer than VFR.

Technical Working Group participants were encouraged to brainstorm any and all conceivable technologies which could conceivably offer solutions to the EFR operating requirements. These candidate technologies were then examined for technical feasibilty and fulfillment of listed constraints. Based on a consensus judgment of each candidate technology by the group, it was given a grade. Grades assigned were "A"; deserves further pursuit, "B"; questionable and "C"; discard. Candidate technologies and their grades are listed in the following table. The reader is cautioned again to resist being misled by shorthand.

Candidate Technology	Grade
1. Enhanced Active BCAS	B
2. Enhanced Integrated CAS	C
3. Augmented ATARS	A
4. Vertical Angle of Arrival	C
5. Automatic Position Announcing System	C
6. Enhanced Full BCAS	B
7. Enhanced DABS CAS	C
8. Combination of (3) and (7)	A

In addition to the foregoing establishment of priorities for further study, the Technical Working Group developed a number of challenging scenarios which should permit math modeling or simulator analysis of candidate technologies.

SECTION II - PROCEDURES WORKING GROUP

OBJECTIVE - Make recommendations and suggest policy and procedures regarding the implementation and use of EFR in the National Airspace System. Our primary concern is operational utility rather than technical feasibility.

DEFINITION - EFR is a system of rules and procedures different from IFR which permits flight of a suitably equipped aircraft by a properly certificated pilot using VFR procedures under Instrument Meteorological Conditions subject to procedural restrictions.

The Procedures Working Group established an opening consensus that EFR as defined deserved a definite place in the ATC hierarchy - superior to VFR operations but not quite IFR. The recommendations of the Procedures Working Group are summarized as follows:

- FAA should pursue the development of EFR and the technical systems which make it possible.

- At the appropriate time FAA should review FAR's, particularly Part 91, so as to initiate rule making to enable EFR.

- EFR will not change the mandatory ATC communications requirement in TCA's, airport traffic areas, and Positive Control Areas. Instrument Approach Procedures which penetrate any area of mandatory communication will not be available to EFR flight.

- Transition from EFR to IFR for controlled terminal area maneuvering and approach should be preceded by EFR advisories from the EFR aircraft and from ATC.

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- MOCA's that apply to IFR will also apply to EFR operations.

- While not normally required, an EFR Flight Plan, like a VFR Flight Plan should be encourated for potential search and rescue assistance.

- EFR flight should use VFR altitudes and the VFR hemispheric rule. No special EFR airspace shall be reserved.

- Pilots wishing to operate EFR must hold an Instrument Rating and meet the IFR recency of experience requirements. In addition some additional training, test and certification to assure understanding of EFR procedures, limitations and responsibilities should be required.

- Part 135 Operations and Airworthiness Requirements should be the same for EFR as they are for IFR with the exceptions that crews must be EFR-qualified and any required special EFR equipment must be an EFR dispatch item.

SECTION III - ECONOMICS WORKING GROUP

The initial effort of the Economics Working Group was to establish some kind of a statistical segment of the airspace user community from which potential EFR operators might be drawn. Picking up the limitations established by the Technical Working Group (under 18,000 ft. and less than 250 knots) the Working Group noted that by the end of the decade of the 1980's,General Aviation including Air Taxi and Commuter Operations was forecasted to account for over half of the IFR aircraft handled by ARTCC's. In addition, it was noted, that for 1978 (the latest year for which activity figures were available at the meeting) over 92% of the active aircraft in the General Aviation Fleet were piston powered single and multi-engined. This category seemed to fit the speed and altitude boundaries set up in discussing Electronic Flight Rules initial applications.

Nearly 40% of these aircraft were operated under Instrument Flight Rules during calendar 1978. All but a couple of thousand of these IFR piston powered airplanes were equipped with ATC radar beacon Transponders. Somewhat less than half had the Transponders equipped with Altitude Encoders.

An effort to assess the rate of probable penetration of this segment of the fleet by EFR was attempted by assessing

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benefits which would be perceived by these operators from EFR qualification. Insufficient data existed during the meeting to quantitfy these benefits in any way, so the benefits exploration had to be limited to a listing without quantification.

System costs would depend to a significant degree on the technical implementation chosen from among the candidate technologies. In view of the constraints chosen by the Technical Working Group, all qualifying systems appeared to be those which were somehow linked with existing navigation or ATC programs either in place or planned. Thus without consciously attempting to get involved in the economics of technical choices the constraint which required initial implementors of EFR to enjoy substantial benefits from the system presumes that the EFR system is based on equipment reasonably considered to be implemented in the fleet at the time EFR gets underway.

By simply identifying issues the Economics Working Group categorized certain cost elements of implementation of EFR. If, for example, the EFR technology chosen works against the existing Transponder Encoder implementation, an implementation expense for Transponders and a significant Encoder implementation would be imposed at least on all IFR-operating airplanes. It is possible that some additional percent of the fleet would be required to carry Transponders and Encoders even for VFR operations in certain airspace in addition to the controlled airspace where such carriage is presently required.

Operators choosing to equip for EFR operations will equip in numbers inversely related to the cost of equipping. A rough analogy to this observation is the implementation profile of the ATC radar beacon Transponder. When, initially, a qualifying Transponder carried a price of $3,000.00 implementation was slow. During the ensuing generations of technology the Transponder price came down into the $600.00 or $700.00 region and the significant implementation of today's fleet is a result. But a benefit must be perceived before this implementation will take place, and the example of the Altitude Encoder is a case in point. It is suspected that those who have installed Altitude Encoders are those who operate in Class I Terminal Control Areas or at altitudes over 12,500 ft., or those who wish to be able to do so at will. So the ticket of admission mandated by airspace regulation constitutes the perceived benefit.

Additional cost of implementing EFR will be incurred by the public in the form of Federal Government expenditures. Certainly additional research and development will be required before EFR can be safely implemented. Then, if the system chosen includes any ground-based (or satellite-based) facilities

their cost of acquisition and maintenance would be borne by the Government. Finally, the Economics Working Group implied that even if the EFR implementation were to be strictly an airborne equipment program the ATC computer system should be configured so that software programming could accommodate the added capabilities of the EFR operator.

APPENDIX I

ATTENDANCE LIST

ASC WORKSHOP

Alzner, Jeanette	UNIVAC
Amlie, Dr. Thomas	Aviation Consultant
Andrews, Dr. John	MIT, Lincoln Laboratory
Barron, B. F.	FAA Air Traffic Service
Becker, Hal	FAA, Air Traffic Service
Berry, Thomas	ARINC Research
Berube, Capt. Roy	Airline Pilot
Burgess, Malcolm	FAA, Office of Flight Operations
Busch, Allen	FAA Technical Center
Butler, Lewis	FAA, Air Traffic Service
Couch, Ellis	FAA Technical Center
DeBaryshe, B. Delano	FAA Technical Center
DelBalzo, Joseph M.	FAA Technical Center
Drouilhet, Dr. Paul	MIT, Lincoln Laboratory
Ebeling, James R.	FAA Technical Center
Eldriedge, Donald	FAA Technical Centere
Feibelman, Lt. Col. Jay F.	USAF Headquarters
Flener, William M.	Aviation Consultant
Foster, Frank	Ransome Airlines
Frisbie, Frank L.	FAA, Logistics Service

Fucigna, Warren	Aviation Consultant
Graham, Walton	QUESTECK
Grossberg, Mitch	FAA Technical Center
Halverson, W. Stanton	Corporate Aviation
Hollister, Dr. Walter M.	MIT, Lincoln Laboratory
Jensen, Dr. Richard S.	The Ohio State University
Karlowicz, Raymond R.	Computer Sciences
Kennedy, Prof. Robert S.	MIT
Koenke, Dr. Edmund J.	FAA, Office of Systems Engineering Management
Kriefeldt, John	Tufts University
Krupinski, Ed	Airline Pilots Association
Link, Gary L.	Boeing Commercial Aircraft Co.
Maupin, Gil	N.J. Department of Transportation
McComas, Art	Bendix Communications
Melson, Edward	National Aeronautics & Space Administration
Miller, Dr. Clyde	FAA, SRDS
Montemerlo, Mel	National Aeroanutics & Space Administration
Montgomery, G. A.	TRW
Neumann, Paul J.	FAA, Office of Systems Engineering Management
Niedringhaus, William P.	MITRE
Orlando, Dr. Vincent	MIT, Lincoln Laboratory
Parks, John L.	National Aeronautics & Space Administration
Popp, Maj. Robert A.	USAF Headquarters

Potts, B. Keith	FAA, Air Traffic Service
Quinby, Gilbert F.	Aviation Consultant
Rovans, D. M.	USAF Headquarters
Rucker, Richard A.	MITRE
Rupp, William E.	Bendix Communications
Shestag, L. N.	E-SYSTEMS, Inc.
Skov, Peter Michael	HH Aerospace
Spangler, R. M.	FAA Technical Center
Steeb, Randall	Rand Corporation
Strum, CC	FAA, Office of Airworthiness
Stutz, Richard G.	Sikorsky Aircraft
Taylor, Quentin S.	FAA, Deputy Administrator
Verstynen, Harry	FAA, Office of Systems Engineering Management
Warfel, Major Joe	USAF Headquarters
Warner, Robert T.	Aircraft Owners and Pilots Association
Wesson, Dr. Robert B.	Rand Corporation
Wetherbie, Lt. Com. Robert F.	USAATCA
White, Frank C.	Air Transport Association
Zellweger, Dr. Andres G.	FAA, Office of Systems Engineering Management

CAVEAT: All available sources of information as to who participated in the ASC Public Workshop were used to compile the above list of attendants. Despite this diligence, it is possible that a small number of people who attended the workshop do not appear on this list due to their failure to sign the Registration thru late arrival or other cause.

APPENDIX II

REPORT ON ELECTRONIC FLIGHT RULES

Thomas S. Amlie

(NOTE: One of the consistent contributors to the EFR concept in Topic Group III of the E & D Initiatives Process was Dr. Thomas S. Amlie. Dr. Amlie's views are based on a respectable background of experience and accordingly he was invited by the Coordinator of the Work Shop to prepare a paper expressing his views. Dr. Amlie's proposed Integrated Collision Avoidance System approach was discussed in the Technical Working Group but failed to achieve consensus support.

Dr. Amlie's ICAS paper is included herewith in full in accordance with a commitment made to the Work Shop in its Closing Plenary.)

... A couple of years ago the FAA sponsored a government/industry discussion called "New E & D Initiatives". This effort was divided into five sub-groups - Sub-Group III, "Freedom of Airspace" was chaired by Gil Quinby. This group met for a couple of days a month and exchanged position papers. One idea which surfaced repeatedly was called "Electronic VFR", "Electronic See-and-Avoid" and several other names, some not printable. Seigbert Poritzky, Director of the FAA's Office of Systems Engineering Management, has correctly perceived that this is too good an idea to let drop and should be examined one more time. I believe that, if we do something sensible and let the idea expand to its full potential, the aviation community, particularly General Aviation, will be greatly in debt to Seig for a long time.

WHAT IS IT?

There were at least as many definitions of this concept as there were participants in Gil Quinby's Group. My definition is as follows: Electronic Flight Rules are such that a pilot can takeoff from where he is and fly to where he wants to be without contacting ATC or filing a Flight Plan. This would obtain in most of the low altitude airspace. If the pilot wanted to fly into a transition zone, TCA, high altitude (above, say, 12,500) or into a controlled airport, he would contact ATC and follow the existing procedures. If he wanted to fly in IMC he would need an Instrument Rating and the flight instruments and navigation equipment as specified by FAR-91. He would also need one more item of equipment in his aircraft, an electronic apparatus which kept him from running into other aircraft. The purpose of this note is to set forth my views as to what this electronic apparatus ought to be. Anyone who has discussed this subject with me knows exactly what I am going to recommend but pray allow me to sneak up on it in my own way. For the present, let us call it by the generic name of a Collision Avoidance Gadget (CAG).

WHAT MUST THE CAG DO?

1. First and foremost, it must reliably prevent collisions. Since it must do this im IMC, it must use radio waves as opposed to say, infra-red. If it is to be the primary means of separation assurance it must do this with a demonstrable reliability of at least 0.9999 or the media and legal profession will have a field day at FAA expense. This definition of reliability assumes that at least one pilot does what he is told and that the other is not trying to cause a collision.

2. The instructions to the pilot should be clear, unambiguous and easy to execute. A low-time pilot in IMC has enough to do without having to monitor an exotic display which adds greatly to his workload.

3. It must indicate, with high reliability, when it is functioning properly and when it is not. Ideally, we would like it to have a reliability/availability of unity but electronic widgets don't do that no matter how well they are designed, built and maintained.

4. It must be affordable. This is very hadr to define. The added convenience and safety might make the commuter/air taxi operator decide that it was a bargain at $5,000 but the private operator who flew only a few hours a year in IMC might be outraged at a price of $2,500.

5. Signal reliability. The signal-in-space format and proce-sing must be such that the incidence of electronic false and/or missed alarms is very low. Operational false/missed alarms are quite a different matter and could start a noisy discussion which could last for days. Briefly, assuming the CAG is working properly, it will or will not give instructions during a given encounter, depending on the logic built into it. What would be an unacceptable near mid-air to one pilot might seem an outrageous waste of airspace to another. I believe that it is mandatory that the CAG function electronically in the pattern at Manassas, Gaithersburg, etc., in VMC. This implies perhaps ten other aircraft within three miles.

DESIRABLE FEATURES

1. Cost as low as possible. Ideally, we would like all aircraft, even those which fly only in VMC, to equip. Almost all mid-airs occur in VMC.

2. Available soon.

3. Universal coverage area. An aircraft owner would be more apt to equip with a CAG if he got service everywhere than he would if he got service only in selected areas. Further, the "Electronic Flight Rules" concept would be significantly less attractive if a pilot had to file an IFR Flight Plan for part of his trip, that part probably being in remote airspace where procedural (non-radar) separation was required.

DISCUSSION

There are basically three contenders for the role of a CAG. These are: DABS/ATARS, BCAS, and some form of Ad Hoc Air-to-Air Collision Avoidance System (ACAS). The present preferred FAA solution is some as yet ill-defined combination of DABS/ATARS and BCAS. I believe that this is the lowest performance and least cost-effective approach and will try to explain why in the following. The basic problem is that synergism does not apply in this case. That is, combining two unreliable, ineffective and expensive systems does not lead to a reliable, effective and low cost result.

DABS/ATARS

Figure 1 shows a map of the United States with 50-mile radius circles drawn around every FAA radar. Thus, if the FAA, with its customary glacial speed converts every radar (at a cost of $1-2 Million each) to DABS, this would be the ATARS service area. It will be seen that many cross-country trips would probably, for at least some part of the flight, be out of effective DABS cover-

age and would have to revert to the inconvenient and inefficient procedural separation techniques. This would largely negate the entire Electronic Flight Rules concept for convenient and expeditious passage. At 50-miles from a DABS sensor the traffic pattern of an airport would be below the DABS coverage floor and arrivals/departures at these airports would have to be handled procedurally with the inherent delays. Perhaps the chief factor mitigating against the use of the DABS for the separation assurance function is the quality of the IPC/ATARS service. Lincoln Laboratory performed a comprehensive flight test of the IPC concept and published an excellent report. (Reference 1) I would urge those who are interested to read this document carefully. My intrepretation is that IPC worked reasonably well for aircraft of roughly the same speed in straight and level flight but that if one aircraft was significantly faster than the other or either one initiated a turn then the service deteriorated rapidly and could cause as many collisions as it prevented. With 20/20 hindsight, this should be no surprise. Ben Alexander predicted to us during the Air Traffic Control Advisory Committee (ATCAC) deliberations of 1968-69, that exactly this would happen. The basic problem is that the ground-based DABS sensor cannot detect a turn until the collision is inevitable. It is my understanding that the DABS/ATARS test program at the FAA Technical Center is showing approximately the same characteristics. Given these results, it will be interesting to see if the FAA General Counsel ever permits this service to be offered to the public.

Another problem with the DABS is the cost of the avionics. Provisions that are now being planned to make DABS compatible with BCAS will increase the already high cost of the DABS Transponder. It must be remembered that one can now purchase a TSO'd ATCRBS Transponder for $500.00 or so and convincing the General Aviation owner that he should spend a great deal more than this for a DABS will be very difficult in view of the quality and quantity (coverage area) of service that he would get.

BEACON COLLISION AVOIDANCE SYSTEM (BCAS)

BCAS means many things to many people. The definition used herein is that it is a Collision Avoidance System that uses the beacon (ATCRBS or DABS) signals in space to perform its functions. Several variants have been built and tried. The basic problem is that the signals in space are about the worst one could conceive of for air-to-air signalling. The multipath problems are such that one could not get the requisite reliability for a system which was the sole basis for separation assurance. In addition, all ATCRBS and DABS equipped aircraft would have to have top and bottom antennas to preclude antenna shielding problems. The Active BCAS presently being evaluated by the FAA Technical Center is apparently working quite well considering these multipath and shielding problems. I believe that it will not demonstrate much above 70% reliability/effectiveness, certainly not the very high performance

required for the Electronic Flight Rules concept. Nonetheless, it is a very valuable project because preventing just one collision involving an Air Carrier is well worth the price of admission.

AIR-TO-AIR COLLISION AVOIDANCE SYSTEM (ACAS)

The ACAS is a system designed specifically to prevent collisions. The signals in space are carefully designed to avoid multipath problems. The first successful ACAS was the time-frequency system of McDonnell-Douglas. It worked quite well but was inherently too costly for General Aviation users. RCA and Honeywell also proposed systems. The FAA arranged with the Naval Air Development Center at Johnsville, PA. to acquire and test these systems. Inasmuch as the Honeywell AVOIDS showed the best performance and also the potential to be by far the least costly, only it will be discussed below.

As delivered, the AVOIDS showed great promise and also some problems with false alarms, missed alarms and a minor problem with multipath. A signal generator was included so as to simulate very high densities of equipped aircraft. The NADC and Honeywell engineers worked closely together to eliminate the problems that were uncovered by flight test.

By the end of the flight test program most of the problems had been resolved. The remaining problems would have required complete rebuilding of the equipment and there was not time and money available to do this. In the final NADC report recommendations are made as to changes to the signal format and processing. The report states that if these changes were made the system would provide a level of performance which would be suitable for EFR. This has, however, not been demonstrated.

The CAS equipments tested all used some form of the ATA Air Navigation/Traffic Control Committee (ANTC) Specification 117 for the threat detection and conflict resolution logic. This logic meets the criterion of giving simple and unambiguous instructions to the pilot and some 400-hours of actual flight test have shown that it reliably prevents collision and requires only very gentle maneuvers (0.1g). In addition, a massive and realistic simulation at NAFEC demonstrated convincingly (Reference 2) that carriage by all aircraft of a CAS using this logic would not degrade the capacity of even the busiest airports and would not add to the controller's workload. This logic was carefully designed by the ATA Working Group so that it would not interfere in the ATC process and would only come into play if someone had goofed.

INTEGRATED COLLISION AVOIDANCE SYSTEM (ICAS)

Even though the ACAS could probably provide the required reliability and performance and the DABS/ATARS and BCAS demonstrably could not, there remains a problem. ICAS costs money. Under contract to the FAA, ARINC performed a cost analysis of the AVOIDS. The conclusion was that it would cost approximately $1,200.00 (1976 $) exclusive of Altitude Encoding. With Encoding and inflation this probably now works out to $2,500.00 or so. I believe that this would be cheaper than the DABS Transponder, but it is still a lot of money and would meet resistance from the General Aviation owner who flew in IMC only infrequently.

One of the best ideas I heard in my years in the FAA was proposed by Dr. Ed Koenke of the Office of Systems Engineering Management. Ed suggested that we build the CAS and the Transponder in the same box and use the RF equipment receivers, transmitter, antennas and cabling and power supplies for both the CAS and Transponder functions. This presupposes that the Transponder manufacturers go to a solid-state transmitter with bandwidth to transmit both at 1090 and 1030 MHz. The Transponder receives interrogations at 1030 MHz and responds at 1090 MHz. The ICAS would both receive and transmit at 1030 MHz. Thus, if the aircraft had a Transponder with upper and lower antennas, a solid-state transmitter and an altitude encoder, the cost to add the ICAS function would be only the cost of the digital logic. I believe that this would be less than $500.00 and propose to build it at home and see if it works.

SUMMARY

The basic problem with any CAS is that the first few people who buy it get very little for their money. It is not until a large fraction of the aircraft which use the same airspace are similarly equipped that there is much benefit. If, however, a National Standard were to be promulgated which made it legal to install a CAS, it seems to me that Airlines, Air Taxi and Commuter aircraft, business aircraft and Flight School and rental aircraft would be equipped fairly quickly for insurance and liability reasons. Although this would not include the majority of the Civil Fleet, it would comprise, based on flight hours in busy airspace, a useful fraction of the total aviation activity.

I believe that the EFR concept has tremendous potential. Several efforts have been made to try to define how we could evolve to such a system from where we are now without requiring something new in participating aircraft. These efforts have all met with failure and will continue to do so. It seems unlikely that anyone will be able to figure out how an ATCRBS/DABS equipped aircraft can share the airspace in IMC with a CAS equipped air-

craft not under ATC control. However, the safety and convenience inherent in the EFR concept is worth our consideration even if the ICAS does cost money. The alternative is the very costly DABS with the ATARS coverage shown in Figure 1 and the IPC/ATARS performance described in Reference 1 and the delays of today's ATC system.

REFERENCES:

1. Lincoln Laboratory, "IPC Design Validation and Flight Testing", Final Report, 31 March, 1978

2. Jolitz, Gordon, "Summary of Results, ATC/CAS Interface Simulation-Phase II A & B", NAFEC Technical Note, 1 February, 1973

APPENDIX III

SUMMARY OF THE ASC BRIEFING SESSION

February 10, 1981

On February 10, 1981, a review of the ASC public workshop was held at FAA Headquarters. The purpose of this review was primarily to allow those people who could not attend the public workshop and expressed a strong interest in the subject a chance to comment on and make recommendations of their own. The review as hosted by Siegbert Poritzky, Director of the FAA's Office of Systems Engineering Management. The participants in this review were:

Gary Cox	-	National Aviation Trades Association
Bev Draughn	-	National Aviation Trades Association
Bill Fanning	-	National Business Aircraft Association
Ed Malo	-	Aircraft Owners and Pilots Association
David D. Thomas	-	General Aviation Manufacturers Assn.
Dennis Wright	-	Aircraft Owners and Pilots Association
G.F. Quinby	-	Workshop Organizer
Siegbert Poritzky	-	Director, Office of Systems Engineering Management, FAA
Ed Koenke	-	Deputy Director, Office of Systems Engineering Management, FAA
Paul Neumann	-	Office of Systems Engineering Management, FAA

Paul Neumann opened the meeting wth a recap of the workshop's agenda, presentations, and discussions. This presentation described the on-going FAA programs pertinent to Alternative Separation Concepts and emphasized the functional difference between an Alternative Primary Separation System and a Collision Avoidance System such as Active BCAS.

The participants at this review expressed disappointment that the most promising technical solutions were far in the future. This group felt strongly that the workshop, in its pre-occupation with technical supplements to the ATC system had

missed the oportunity to discuss some short-term procedural approaches. There was a clear consensus that we didn't have to wait for ATARS and AERA to be implemented in order to come up with a better procedural solution to the release of an IFR departure from a suburban airport. The group recommended that an informal ATC System Procedures Refinement Group structured similar to the Cloud Nine Aviation Weather Discussion Group be formed. This would permit a discussion of solutions to operating problems which appeared implementable and effective to system users with the Air Traffic Service and other FAA and non-FAA representatives involved.

They also suggested that considering the timeframe during which an ASC capability might be provided that it was too early to preclude satellite-based navigation, surveillance and communication. A satellite-based system would increase coverage in mountainous area of the country. The participants discussed the possibility that future launch and operational efficiencies may make a satellite-based system economically feasible. No firm consenus was reached.

Serious question was raised at the decision of the Procedures Working Group to implement EFR at VFR hemispheric altitudes. Several at the meeting found this decision flawed and recommended strongly that it be reviewed and reversed. It was pointed out that there are only two sets of altitudes available; VFR and IFR and that this recommendation reduced vertical separation during IMC to 500 feet below FL 290. The procedures working group was aware of this. They assumed that technical developments would take place before EFR was permitted in order to allow this with no reduction in safety.

There was discussion on the workshop's recommendation that there be an EFR endorsement on the IFR license and other potential certification aspects of EFR. It was noted that an improved method of disseminating aviation weather information would enhance the safety of both IFR and EFR flight and that the FAA should investigate methods for accomplishing this.

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